Streamflow Characterization at Zion National Park, Utah

by

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1.0 SCOPE OF THE STUDY

The purpose of this study is to provide a comprehensive description of the hydrological characteristics of surface runoff at Zion National Park and surrounding watersheds. The analysis is focused mainly on the North Fork of the Virgin River which traverses across the most popular portion of the National Park. The study is also extended, although in less detail, to other streams in the area such as the East Fork of the Virgin River, La Verkin Creek, North Creek, and Kolob Creek, all part of the same hydrologic region. The discussions presented in this report are aimed at providing the reader with an in-depth understanding of the structure of surface flow in the region, as well as the causal factors for their characteristics. Time series of surface runoff are analyzed at annual, monthly, and daily time intervals. The narrative description of the findings is accompanied by several graphs and tables.

The report is organized in the following manner. Chapter 2 defines the general area of interest for the study and provides basic physical information of the streams network. Chapter 3 summarizes all the existing records of surface water within the area of interest. Chapter 4 provides an in-depth characterization of the flow regime of the North Fork of the Virgin River, covering the structural aspects of flow time series at several time intervals; Chapter 4 also presents the bulk of the results of the study. Chapter 5 concentrates on the distribution of flood events in the North Fork of the Virgin River and the frequency analysis of high- and low-flow variables. Finally, Chapter 6 provides a sense of the variability of flows at the North Fork of the Virgin River by means of flow duration analysis. Chapter 6 also introduces a parametric flow duration analysis for the whole Zion region that has the potential to estimate flow availability and variability at any ungaged site in the region. Appendixes I and II contain results from computations introduced in Chapter 4.

Because of the vast number of specialists providing technical support to the Zion project, this report may not satisfy all information needs. If this is the case, special requests for further investigation of hydrological aspects at Zion National Park should be directed to the Zion Project manager for their prompt attention.

2.0 STUDY AREA

2.1 Location

Very comprehensive descriptions of the general area of the Upper Virgin River Basin, which includes Zion National Park, can be found in several reports and publications. Among them, the USGS (1950) and the Utah Division of Water Resources (1983) provide complete background information. For the purpose of this study, the description presented herein will be limited to the main features characterizing the flow network of the Virgin River and its tributaries upstream from the city of Virgin.

Zion National Park is located in the south-western corner of the State of Utah within the Virgin River drainage basin, Figure 1. The North and East Forks of the Virgin River together with several other smaller tributaries of the Virgin River drain the Park. The Park's boundaries encompass 231.3 square miles (148,050 acres) with elevations ranging from around 8000 feet above sea-level in the uplands to 4000 feet at the Park's headquarters. Figure 1 depicts the boundaries of Zion National Park and the major basins conforming the headwaters of the Virgin River. The principal water courses constituting the Virgin River are, from West to East: La Verkin Creek, North Creek; the North Fork of the Virgin River (NFVR) and its tributaries, and the East Fork of the Virgin River (EFVR). The Virgin River collects surface runoff from the above mentioned streams, running east to west from the confluence of the EFVR and the NFVR. With the addition of the Kanab Creek basin (located outside the Upper Basin of the Virgin River), the hydrologic units that constitute the general area of interest for this study are defined.

2.2 Maps Inventory

Most of the topographic information incorporated in this report was extracted from topographic maps prepared by the U.S. Geological Survey at scale 1:24,000, dated 1950 to 1986. Table 1 contains an inventory of 31 topographic maps utilized to cover the area occupied by Zion National Park and its adjacent watersheds. Table 1 also is accompanied by Figure 2 which displays the relative position of the maps.

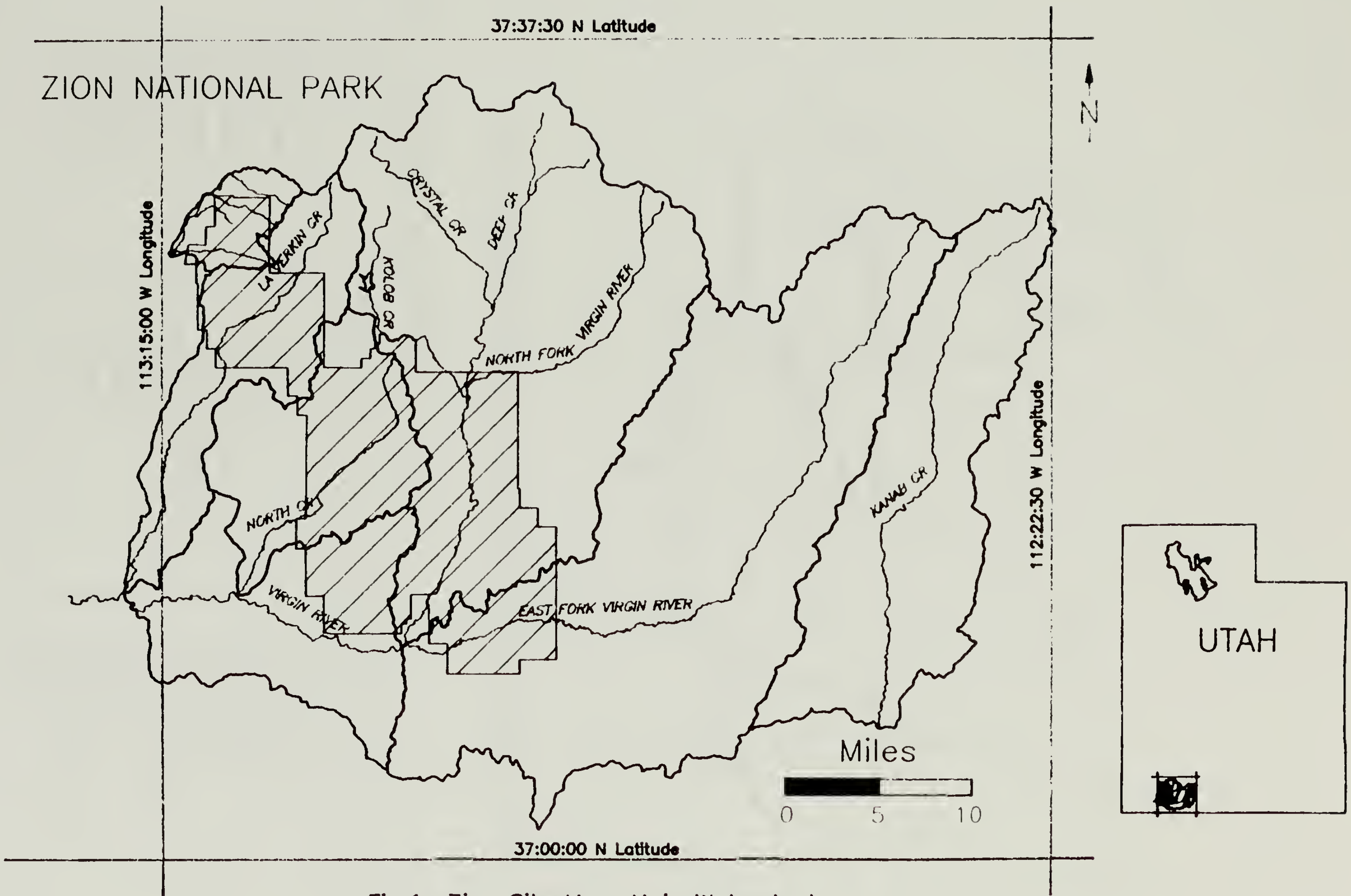

Fig.1 Zion Site Map, Main Watersheds

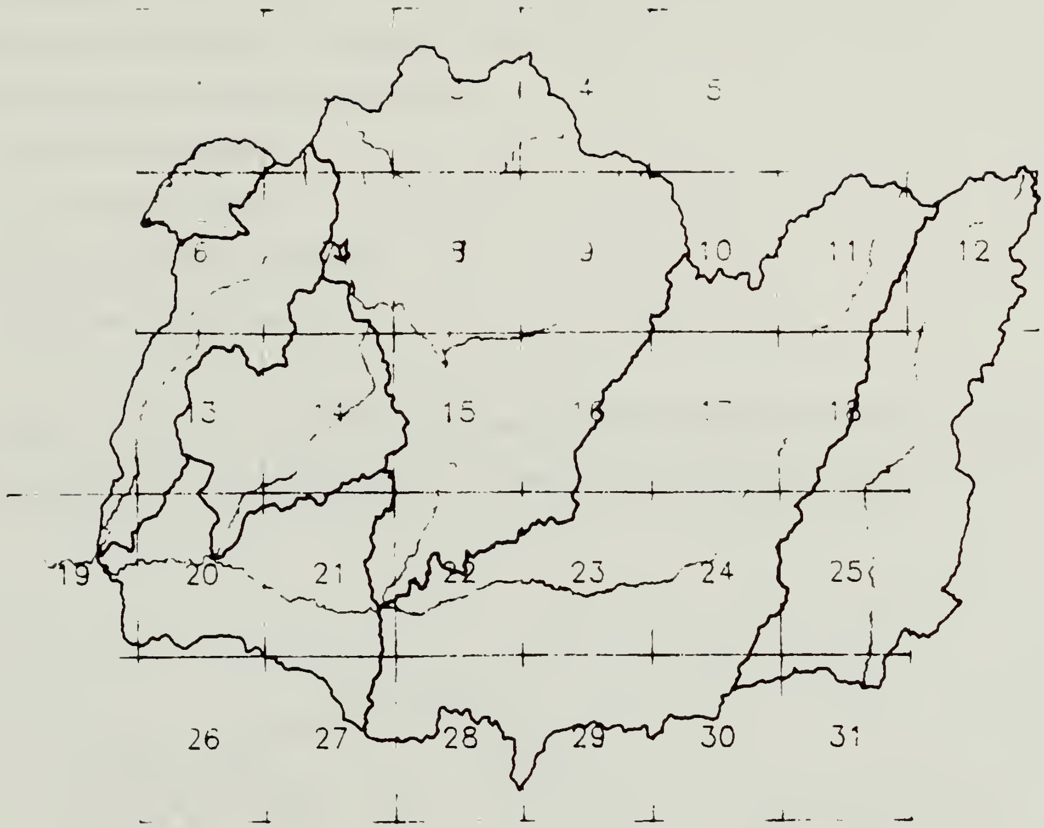

Fig.2 USGS Maps Covering Zion National Park and Adjacent Areas

Table 1. Topographic Maps Inventory

Pos.	Map Name	Pos.	Map Name	Pos.	Map Name
1	Kanarraville	11	Long Valley Junct.	21	Springdale West
2	Cedar Mountain	12	Alton	22	Springdale East
3	Webster Flats	13	Smith Mesa	23	The Barracks
4	Navajo Lakes	14	Guardian Angels	24	Mount Carmel
5	Henrie Knolls	15	Temple of Sinawava	25	White Tower
6	Kolob Arch	16	Clear Creek Mount.	26	La Verkin 4 S.W.
7	Kolob Reservoir	17	Orderville	27	Smithsonian Butte
8	Cogswells Point	18	Glendale	28	Hildale
9	Straight Canyon	19	Hurricane	29	Elephant Butte
10	Strawberry Point	20	Virgin	30	Yellow Jacket Canyon.
				31	Kanab

2.3 Drainage Areas

The maps listed in Table 1 provided the basic geographical information for the development of a Geographic Information System (GIS) for the area of interest. At present, the following thematic layers are available:

- watersheds boundaries
- river drainage network
- Zion National Park boundaries
- streamflow gaging stations

Figure 3 shows the main basins delineated by the thicker lines, and in turn, each basin segmented into several subbasins, as shown by the lighter green lines.

Fig.3 Watersheds Subdivision in the Vicinity of Zion N.P.

The GIS was used to compute areal measurements for all the basins and subbasins delineated in Figure 3. Area measurements are used to better describe the hydrological setting of the streams network, and to support future hydrologic analysis and modeling efforts in the area. Contributing drainage areas were measured at points of obvious interest such as at the confluence of streams, location of streamflow gaging stations, field study sites, etc. The results of the area measurements are included in Table 2, together with some stream length measurements.

Table 2. Drainage and Stream Length Measurements

Watershed Name	---Drainage Area (mi^2)---			River Length (mi)	
	------ Partial -----		Total	Partial	Total
KANAB CREEK SUB-AREA			191.92		
Kanab Creek		191.92		38.74	
EAST FORK VIRGIN RIVER SUB-AREA			409.49		
East Fork V.R.		187.40			52.17
above Site (2)	35.62			13.49	
between Sites (2) and (3)	127.75			34.57	
between Site (3) and confluence	24.03			4.11	
Stout Creek		23.52			
Lydias Creek		15.03			
Muddy Creek		36.47			
Meadow Creek		47.65			
Rock Canyon		26.46			
Yellow Jacket		30.30			
Shunes Creek		37.66			
NORTH FORK VIRGIN RIVER SUB-AREA			354.01		
North Fork V.R.		123.61			
above Site (10)	89.77				
between Sites (10) and (12)	22.69				
below Site (12)	11.15				
Deep Creek		127.87		18.11	
Kolob Creek		29.43		16.82	
Orderville Creek		40.67			
Clear Creek		32.43			

NORTH CREEK SUB-AREA			99.38		
North Creek		99.38			19.36
above Site (14)	94.99			16.19	
below Site (14)	4.39			3.17	
VIRGIN RIVER SUB-AREA			115.75		
Virgin River		115.75			25.18
above Site (15)	84.37			11.91	
below Site (15)	31.38			13.27	
LA VERKIN CREEK SUB-AREA			119.18		
La Verkin Creek		95.98			31.69
above Site (16)	95.98				
Spring Creek		6.21			
Camp Creek		9.54			
Taylor Creek		7.45			

2.4 Streams Network

The following description of the stream network is carried out from the water system's point of view. That is, not just looking at the problem within the political boundaries of the National Park, but extending the analysis at areas adjacent to the Park as well. Figure 4 shows the Virgin River basin subdivided into several subareas. The subareas have been named according to the nomenclature adopted by the Utah Division of Water Resources (1983). They are from west to east: Hurricane-La Verkin, Virgin-Springdale, North Creek, North Fork of the Virgin River, and East Fork of the Virgin River. These five subareas constitute the Upper Basin of the Virgin River. The sixth subarea shown in Figure 4, Kanab Creek, although it does not belong to the Virgin River basin, has been included as part of the study area in order to extend the boundaries of the hydrological analysis as explained later in Section 6. The subareas shown in Figure 4 were purposely detached from each other to emphasize the independence of the stream runoff.

Figure 4 shows basic information of the stream networks within each subarea. The drainage network has been digitized from the USGS topographic maps indicated earlier, where all perennial streams and only the most important ephemeral water courses were included in the process. Following the quantitative classification of channels network suggested by Horton (Bras, 1990) and based on the level of resolution adopted during the

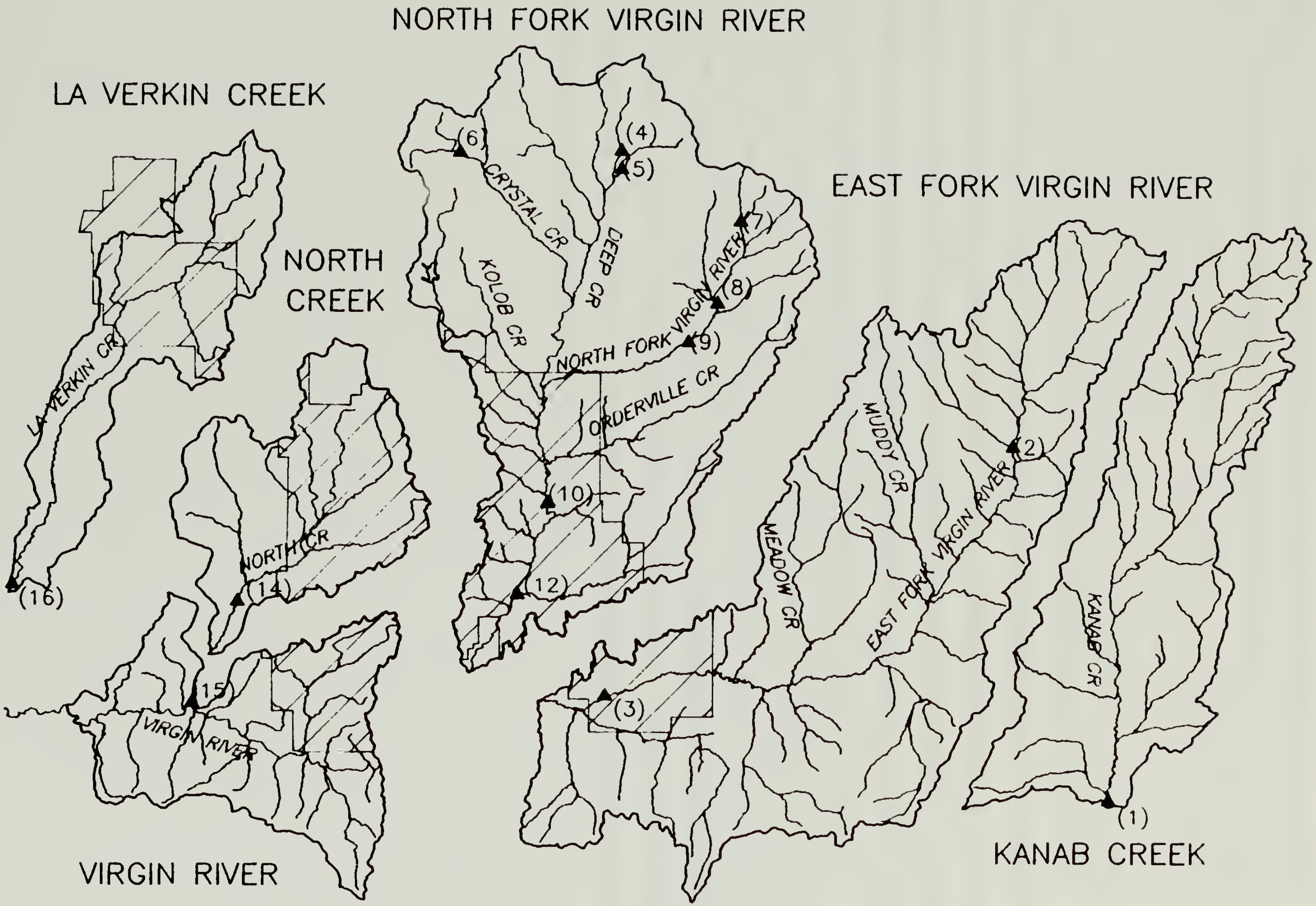

Fig.4 Hydrologic Subareas of Upper Virgin River Basin

digitizing process, the most downstream portion of the EFVR and NFVR reach a stream order of 4. Consequently, after the junction of these two streams which form the Virgin River, the Virgin River itself (within the Virgin River subarea) has a stream order of 5. Figure 4 also shows 16 sites, denoted with red diamonds, indicating the location of the surface-water gaging stations operated by the U.S. Geological Survey.

The two major contributors of water to the Upper Virgin River, the North and East Forks of the Virgin River, constitute the two largest subareas depicted in Figure 4. Within these two subareas, the Park is located in the most downstream portion of the basins. This situation makes the Park's aquatic resources highly vulnerable to changes in the hydrologic regime occurring at the headwaters and intermediate reaches of the streams. The section of the Park within La Verkin Creek subarea can also be impacted by development upstream, since a considerable portion of La Verkin Creek headwaters lies above the Park. Conversely, the areas of the Park within North Creek and the Virgin/Springdale subareas occupy the upper portion of the headwaters, and consequently, are less likely to be affected by development upstream from the Park. Finally, a small section of the Park extends west of La Verkin Creek into three small tributaries of Ash Creek. They are: Spring Creek, Camp Creek, and Taylor Creek. The location of these streams and their corresponding subbasins are shown in Figures 1 and 3 respectively.

3.0 STREAMFLOW RECORDS AVAILABLE

3.1 USGS Streamflow Gaging Stations

Records of surface runoff in the area of interest are available for several USGS gaging stations as indicated in Table 3. The Site No. helps to locate the gaging station in Figure 4. The USGS No. and Station name are as given by the USGS. Latitude, longitude, elevation, and drainage area were also provided by the USGS. Each period of analysis includes only those water-years with complete records at the station. The number of water-years with complete records is also indicated, since some records are fragmented (with water-years missing). Historic mean annual flow for the period of record is indicated as discharge, in cubic-feet per second, and as annual volume, in thousands of acre-feet per year. Table 3 also provides remarks concerning the degree of regulation of the streams and offstream water diversions affecting flow measurements.

All gaging stations listed in Table 3 are located in the same hydrologic region, the Upper Basin of the Virgin River, except for the station at site No.(1), Kanab Creek near Kanab, which belongs to the Kanab drainage area. This station was included to expand the boundaries of the study to areas with hydrologic conditions similar to the rest of the stations, and that can potentially contribute to the hydrologic information for the whole region. It should be also noted that flow records at Site (12), USGS No. 09405500, and at Site (13), USGS No. 09405501, refer to the same gaging station, located in the North Fork of the Virgin River near Springdale, one hundred feet from Park headquarters. Figure 4 shows only Site (12) for that reason. However, the corresponding flow records are different. The USGS published flow records for No.09405501 as the flows actually registered at the gaging station. On the other hand, the record for No.09405500 is a combined flow, which considers river flows at the gage plus flows diverted by the Springdale Canal (USGS No. 09405499), located a short distance upstream of the gaging station. Flow measurement at the Springdale Canal was discontinued after 1988, when the conveying system was changed from an open channel to a closed conduit. Since then, water diversions to the City of Springdale can only be estimated based on the past records.

3.2 NPS Streamflow Gaging Stations

The National Park Service operated continuous recording gaging stations on the North Fork and the East Fork of the Virgin River from June 15, 1988, to June 13, 1989. Their locations are indicated in Figure 4 as Sites (10) and (3) respectively. Although a very short period of record, data collected at these stations were used to determine mean daily and mean monthly flows for the period over which the gages were operated (Hermes, 1991). During that same period of time, several discharge measurements were made at both locations with the purpose of developing stage-discharge relationships.

Unfortunately, water years 1988 and 1989 were at or below average in terms of total discharge for the whole region, impeding the measurement of very large peak flows at either stream. Measurements of streamflows at the NPS stations were part of a series of studies conducted in the area to assess potential changes of the park's water related resource attributes resulting from alterations in the hydrological regime.

Through a cooperative agreement between the U.S. Geological Survey and the National Park Service, two new gaging stations were installed in the old NPS locations during the summer of 1991. Data collection at these two new stations started in October 1991. Recently, a third station was installed in La Verkin Creek, before the stream leaves the Park. The station was installed and is being operated by the National Park Service since the spring of 1992.

3.3 Period of Record for Gaging Stations

The periods of record for surface runoff as recorded by the USGS and NPS gaging stations are also displayed in Figure 5 in the form of a bar diagram. The bars allow the reader to readily compare the period of record available for a particular station in relation to the periods for the rest of the stations. The station at Site (17) shows practically no period of record because of its very recent installation (March 1992). Records for stations (3) and (10) include the period June 1988-June 89 (indicated as water year 1989) when they were operated by the NPS, and since October 1991 under USGS operation.

Table 3. Surface Runoff Gaging Stations in the Area of Zion N.P., Utah.

Site No.	USGS No.	Station Name	Latitude	Longitude	Elevat. [feet]	Drainage Area [mi²]	Period of Analysis 19__	Period of Analysis No.Yrs	Mean Annual Flow [cfs]	Mean Annual Flow [Ac-Ft]	Remarks
(1)	09403600	KANAB CREEK near KANAB	37:06:02	112:32:50	5060.	198.0	79-90	12	14.63	10,568.	no diversions above station
(2)	09404450	E.F. VIRGIN Rv. near GLENDALE	37:20:19	112:36:13	5900.	74.0	67-91	25	19.37	14,015.	few diversions abo. station
(3)	09404900	E.F. VIRGIN Rv. near SPRINGDALE	37:09:51	112:57:27	4700.	284.0	89,	1			1989 under NPS operation
(4)	09405200	DEEP CREEK near CEDAR CITY	37:31:18	112:53:01	7680.	6.7	88-91	4	1.64	1,187.	some diversions above stat
(5)	09405250	E.F. DEEP CREEK near CEDAR CITY	37:30:35	112:52:58	7640.	7.8	88-91	4	2.84	2,051.	some diversions above stat
(6)	09405300	CRYSTAL CREEK near CEDAR CITY	37:31:20	113:01:25	8320.	10.0	57-61	5	7.25	5,234.	
(7)	09405400	N.F. VIRGIN Rv. near GLENDALE	37:28:22	112:46:40	7530.	5.7	73-78	6	5.02	3,624.	
(8)	09405420	N.F. VIRGIN Rv. blw BULLOCK CANYON	37:25:06	112:47:59	6420.	30.0	75-84	10	19.64	14,307.	
(9)	09405450	N.F. VIRGIN Rv. abo. ZION NARROWS	37:23:26	112:49:30	6000.	42.0	79-84	6	25.67	18,546.	
(10)	09405490	N.F. VIRGIN Rv. above BIG BEND	37:16:43	112:56:28	4400.	288.0	89,	1			1989 under NPS operation
(11)	09405499	SPRINGDALE CANAL nr. SPRINGDALE	37:12:42	112:58:33	3970.	- - .-	69-88	20	6.50	4,700.	
(12)	09405500	N.F. VIRGIN Rv. near SPRINGDALE	37:12:35	112:58:40	3970.	344.0	26 & 28-88	62	104.48	75,718.	minor regulation (Kolob) Springdale canal included
(13)	09405501	N.F. VIRGIN Rv. near SPRINGDALE	37:12:35	112:58:40	3970.	344.0	69-72 & 74-91	22	109.00	78,900.	some diversions abo. stat.
(14)	09405900	NORTH CREEK near VIRGIN	37:14:14	113:09:01	3680.	97.0	86-91	6	6.17	4,455.	some diversions abo. stat.
(15)	09406000	VIRGIN RIVER at VIRGIN	37:11:53	113:12:22	3440.	934.0	10-71 & 79-91	75	201.89	146,254.	some diversions abo. stat.
(16)	09406150	LA VERKIN CREEK near LA VERKIN	37:12:17	113:17:03	3040.	91.0	86-91	6	8.45	6,105.	some diversions abo. stat.
(17)	NPS	LA VERKIN CREEK within ZION N.P.									recently installed

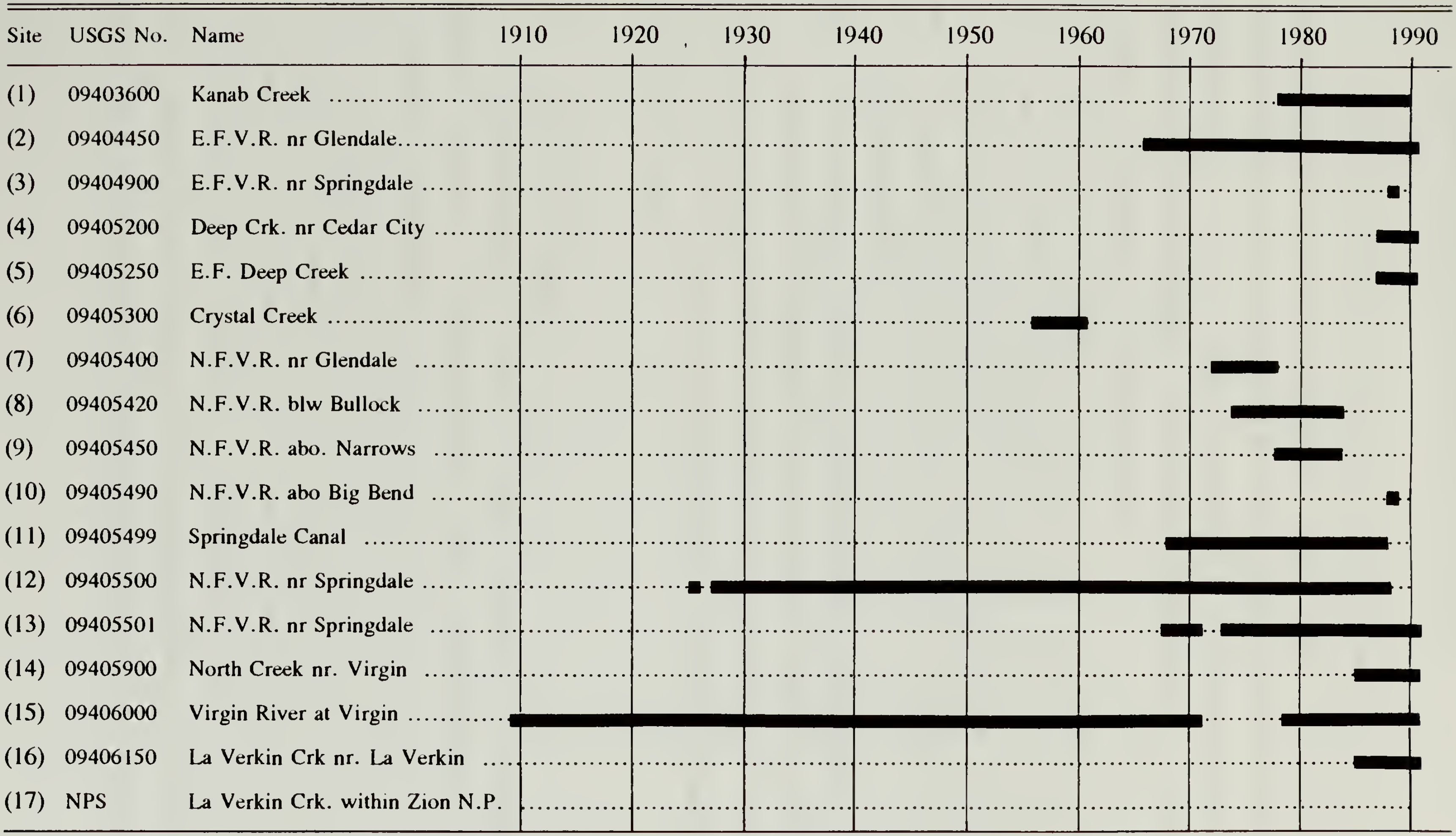

Fig. 5 Period of Record of Surface Runoff Gaging Stations

4.0 STRUCTURE OF SURFACE RUNOFF

Despite some expected differences in flow characteristics according to the order of the stream being analyzed, all watercourses in the upper-basin of the Virgin River display the same typical flow pattern of rivers in the semi-arid region of the Western United States. For the purpose of this study, an in-depth characterization of the flow regime of the North Fork of the Virgin River at Springdale, USGS station No.09405500 was carried out. The reasons for selecting that particular river location are:

☞ The NFVR is one of the most threatened rivers in the Park at the present time.

☞ Station No.09405500 is strategically located in the downstream portion of the stream. Thus, it captures all hydrological changes occurring in the headwaters of the basin.

☞ The gaging station is also close to the reach of the river selected by the NPS for ecological studies.

☞ The station has a relatively long period of flow record available.

Gaging station No.09405500, on the North Fork of the Virgin River, is located 1.9 miles upstream from the town of Springdale, and in the proximity of Zion National Park visitors center. The station is located approximately 7 miles downstream from the study site selected by the NPS.

4.1 Annual Time Series

This analysis of flow time series begins at the annual level, which is the largest time-interval of analysis for a periodic process. Figure 6 displays historical annual discharge (in volume units) at Springdale from year 1926 to 1991 (1927 excluded), a total of 65 years. The average annual discharge for that period is 74,200 ac-ft (102.4 cfs). Due to the interruption of flow measurements at the Springdale Canal after water-year 1988, annual flow at Springdale for water-years 1989, 1990, and 1991 was computed as the flow measured at the station plus 4,700 ac-ft, which is the average annual canal diversion for the period 1969-1988. Any inaccuracy introduced by this procedure affects only the last three years of the series, and it is considered minor when analyzing flows at the annual scale.

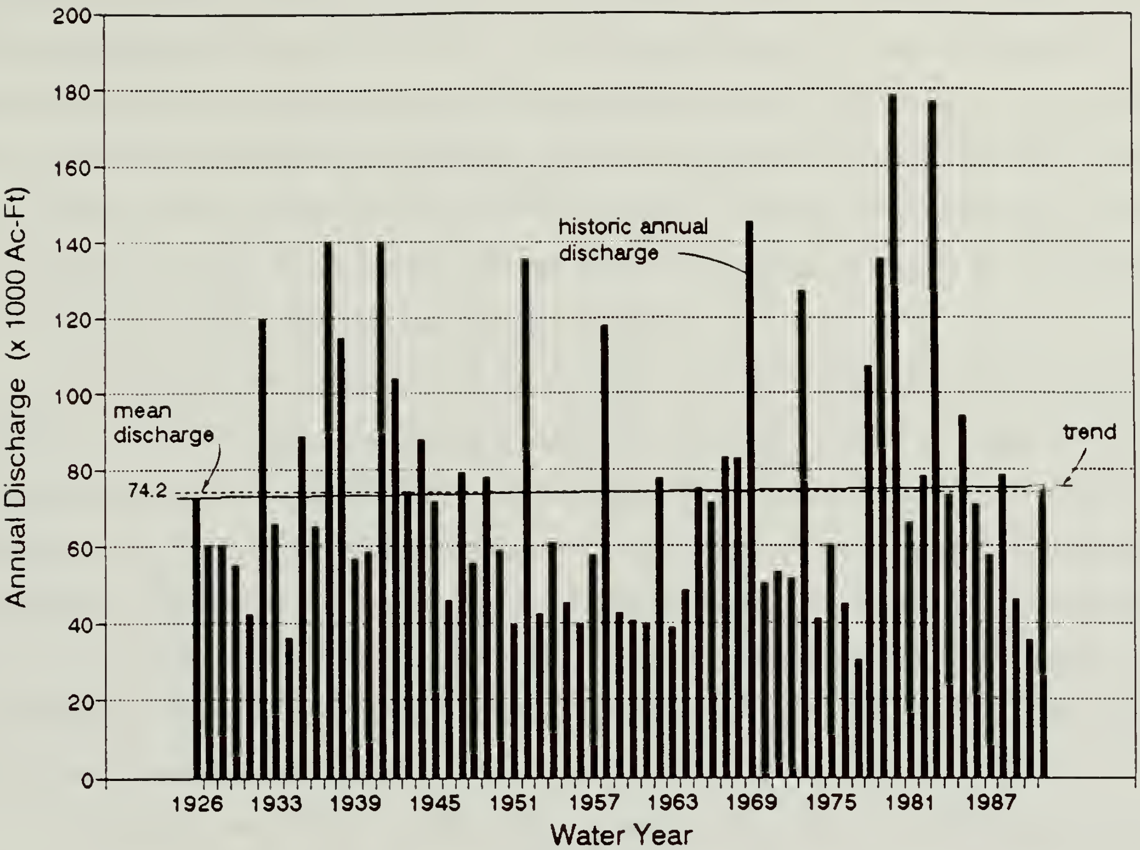

Fig. 6 Fluctuations of Annual Discharge of the NFVR at Springdale

The total annual discharge measured at Springdale acts as a macroscale integrator of all processes in the watershed up to that point, from which it is possible to detect changes in the hydrologic environment, either by slow evolution in nature or by human activities. In other words, the annual time series should allow us to infer the existence of long-term trends or jumps in the series parameters along the period of record. Annual runoff series in natural systems are typically non-correlated in time. The annual flows at Springdale exhibit acceptable levels of independence, with a serial autocorrelation coefficient of about 0.11, slightly lower than the average value for rivers in the Western United States.

Kolob Reservoir, located on Kolob Creek, Figure 4, is the only storage system built in the NFVR system. The presence of Kolob Reservoir, since 1957, raises the question as to what degree natural flows have been affected by the operation of the reservoir. The ratio

between the maximum storage capacity of the reservoir (5,600 ac-ft) and the mean annual flow at Springdale (76,000 ac-ft) is 0.07. This relatively small ratio (7%) indicates the reduced capability of Kolob Reservoir to regulate flows in the NFVR system. The complete series of annual discharge at Springdale [1926-1991] was split into two sub-periods, the first from 1926 to 1956, and the second from 1957 to 1991. The two subsamples were used to test whether there was an appreciable change in the mean annual discharge for the periods before and after Kolob reservoir entered into operation.

The Student-t test indicated that the change in average annual discharge for the two subperiods, a 2% increase, is statistically insignificant at the two-tailed 5% confidence level. Thus, it could be concluded that there is no appreciable change in total annual runoff at Springdale due to the effect of Kolob Reservoir. However, it should be noticed that annual precipitation at Zion (NOAA station No. 9717) for the second sub-period (15.7 inches) is 12.9% larger than for the first sub-period (13.9 inches). This appreciable increase in precipitation is likely to conceal any decrement in total annual runoff due to water losses and withdrawals from Kolob Reservoir.

In a natural and relatively undisturbed system like the NFVR, inconsistency in data can only be produced by systematic errors in flow measurements which, fortunately, were neither reported nor detected at this station. Only the natural stochastic variation between wet, normal, and dry water years can be observed. The computed upward trend of the annual series, suggested in Figure 6 by the unbroken line, has no statistical significance at the 5% confidence level. That is, the slope of the regression line is statistically not different from zero.

Extreme values of annual discharge are also of interest. Figure 7 displays, in the same graph, the maximum, the average, and the minimum mean-daily flows (in cfs) that occurred each year, using two scales. Minimum annual flows have an average value of 33.7 cfs and a standard deviation of 6.1 cfs, indicative of the practically constant minimum base flow at Springdale year after year. Average annual discharge, with an average value of 102.4 cfs, displays natural variability with a standard deviation of 47.8 cfs. As expected, the variation of maximum annual flows is larger than for the previous two statistics, with an average value and standard deviation of 866.7 cfs and 784.2 cfs respectively. The large

variance is mainly due to three very large flow events occurring during water years 1938, 1967, and 1980.

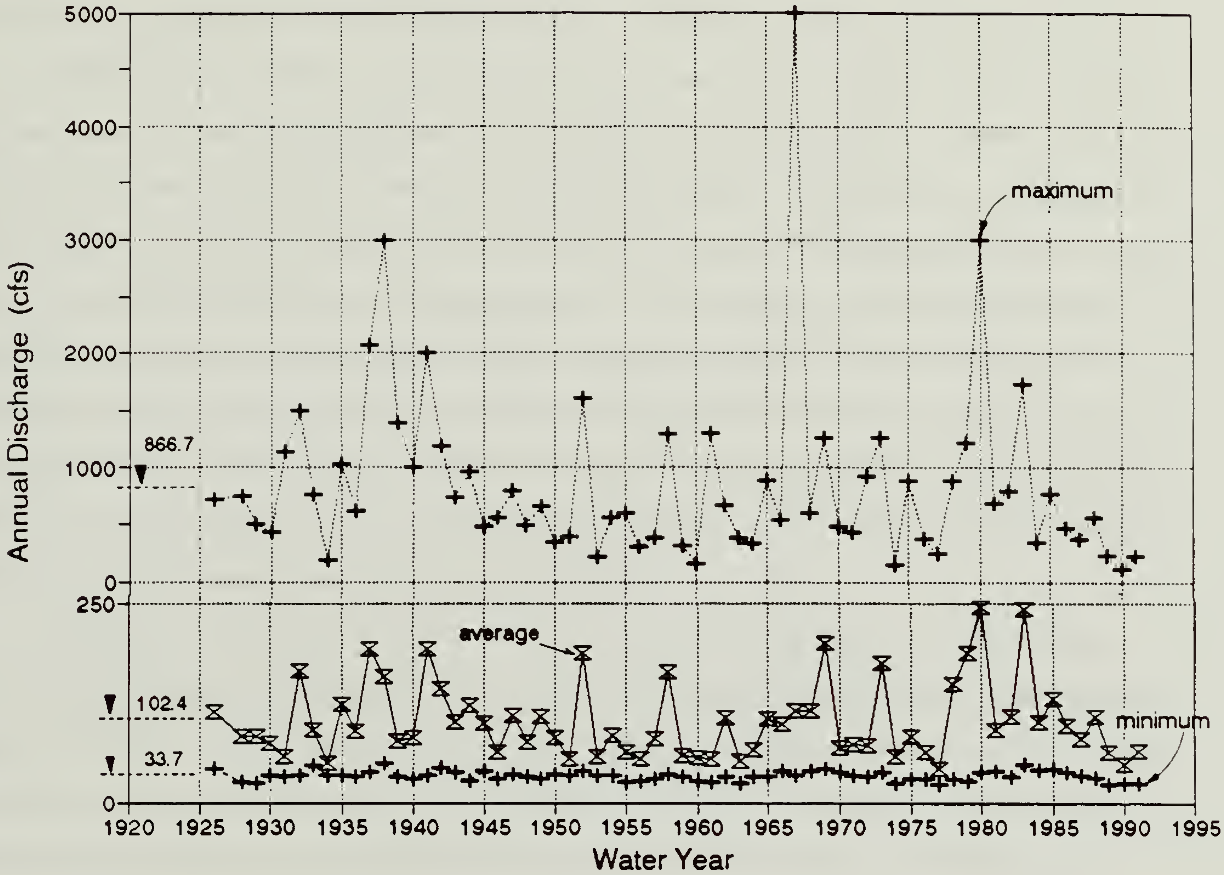

Fig. 7 Annual Series of Average and Extreme Daily Flows of the NFVR at Springdale

The hypothesis of negligible trends in the annual series of average and extreme mean-daily flows was also tested utilizing the Student-t test. They were found insignificant in a two-tailed test at the 5% confidence level. These findings assure the homogeneity of the series of annual discharge of the NFVR at Springdale.

4.2 Monthly Time Series

The analysis of periodic time series like monthly flows is more complex than for annual series due to the influence of the annual cycle, which introduces periodic variations in the statistical characteristics of the former series. This section presents a discussion of the basic statistics for the monthly time series of flows in the NFVR. Figure 8 shows a long-term sequence of mean-monthly flows at Springdale, from 1926 to 1988. Water years 1989 through 1991 were excluded for the reasons explained earlier. This series has a long-term mean value of 104.5 cfs indicated by the dashed line. Despite the plotting of all those many years of monthly information on a single graph, it is still possible to appreciate the basic structure of periodicity and the high stochastic variability typical of mean-monthly flows. It is important to notice that 95% of the mean-monthly flows are below the 300 cfs level. Of the remaining 5% of flow events, shown in the graph by the sharp spikes that reach above 300 cfs, practically all of them occur during the months of April (40%) and May (54.3%), with only 2 events during the month of June (5.7%).

Periodicity in the mean-monthly flow series should be viewed as a deterministic processes, governed by physical mechanisms such as rainfall and snowmelt. From October through mid-March, when precipitation on the drainage is mostly in the form of snow, the river flow consists almost wholly of ground-water discharge. The largest mean-monthly flows began in April and continued through June. During that period, the hydrograph resembles that of a typical snowmelt season in high mountainous regions. After the snowmelt season is over, from July to September, the river peaks several times in response to runoff-producing rains. During the snowmelt and summer thunderstorms season, overland runoff is predominant over ground-water contribution.

The information embedded in the long term sequence of mean-monthly flows can be summarized by the three histograms shown in Figure 9, which represent the maximum, the average, and the minimum mean-monthly flows during the whole period of record for each month, starting in October and finishing in September. The histogram of maximum mean-monthly flows displays particularly large values for the months of December and February. Flood events that occurred in December of 1967 and February of 1980 are the reason for the irregular shape of the histogram.

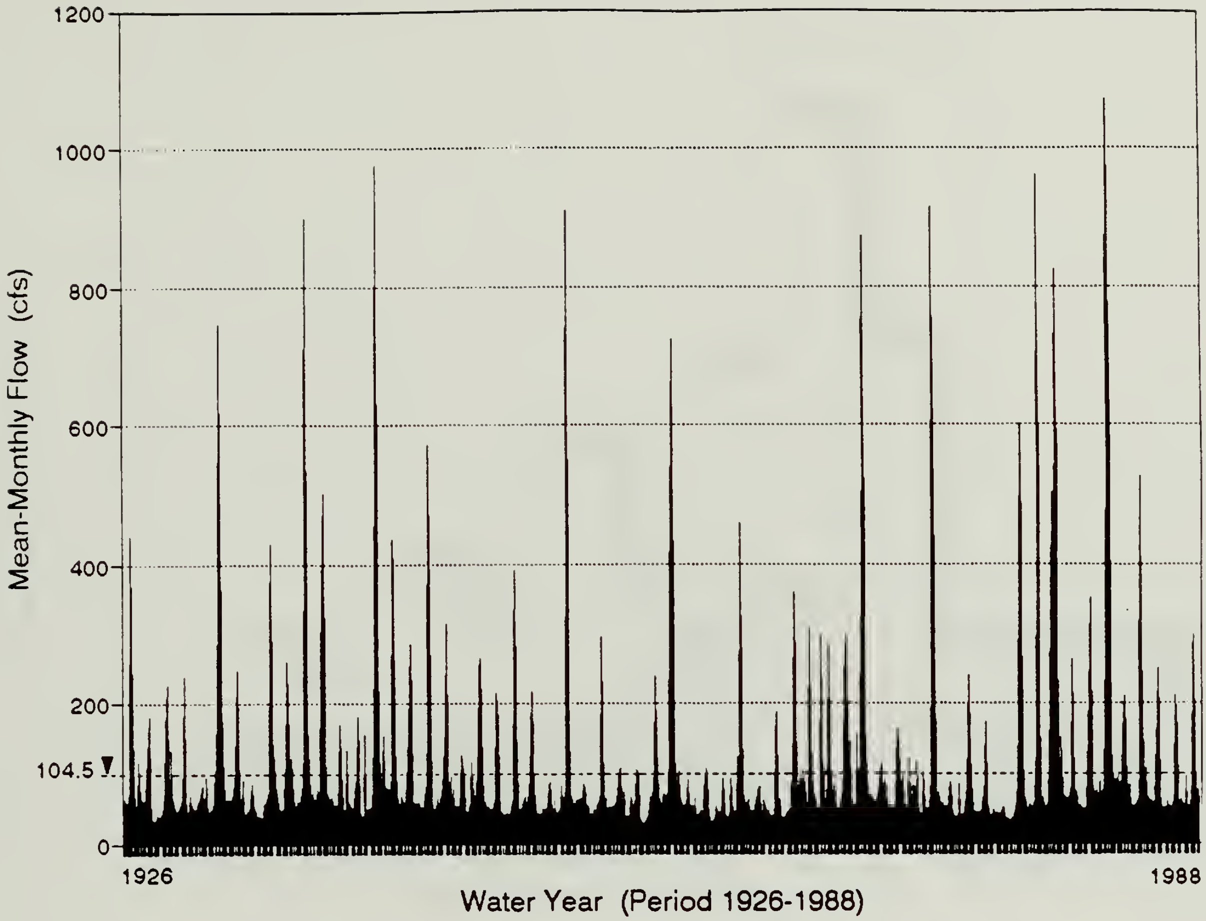

Fig. 8 Long-Term Trace of Mean-Monthly Flows of the NFVR at Springdale

Hermes (1990) assessed the hypothesis that the distribution of mean-monthly flows at Springdale is different for the periods before and after the operation of Kolob Reservoir. Her analysis utilized a nonparametric method, the Wilcoxon rank sum test, to conclude that for every month of the year, the pre- and post-dam mean-monthly flows are derived from the same population. The null hypothesis (no difference) was proved at a 5% significance level. In other words, there is no significant difference in the structure of monthly flows before and after the construction of Kolob Reservoir. If a significance level of 10% is selected, the null hypothesis would still be accepted for all months except September, implying that there is a difference between pre- and post-dam monthly flows for that particular month.

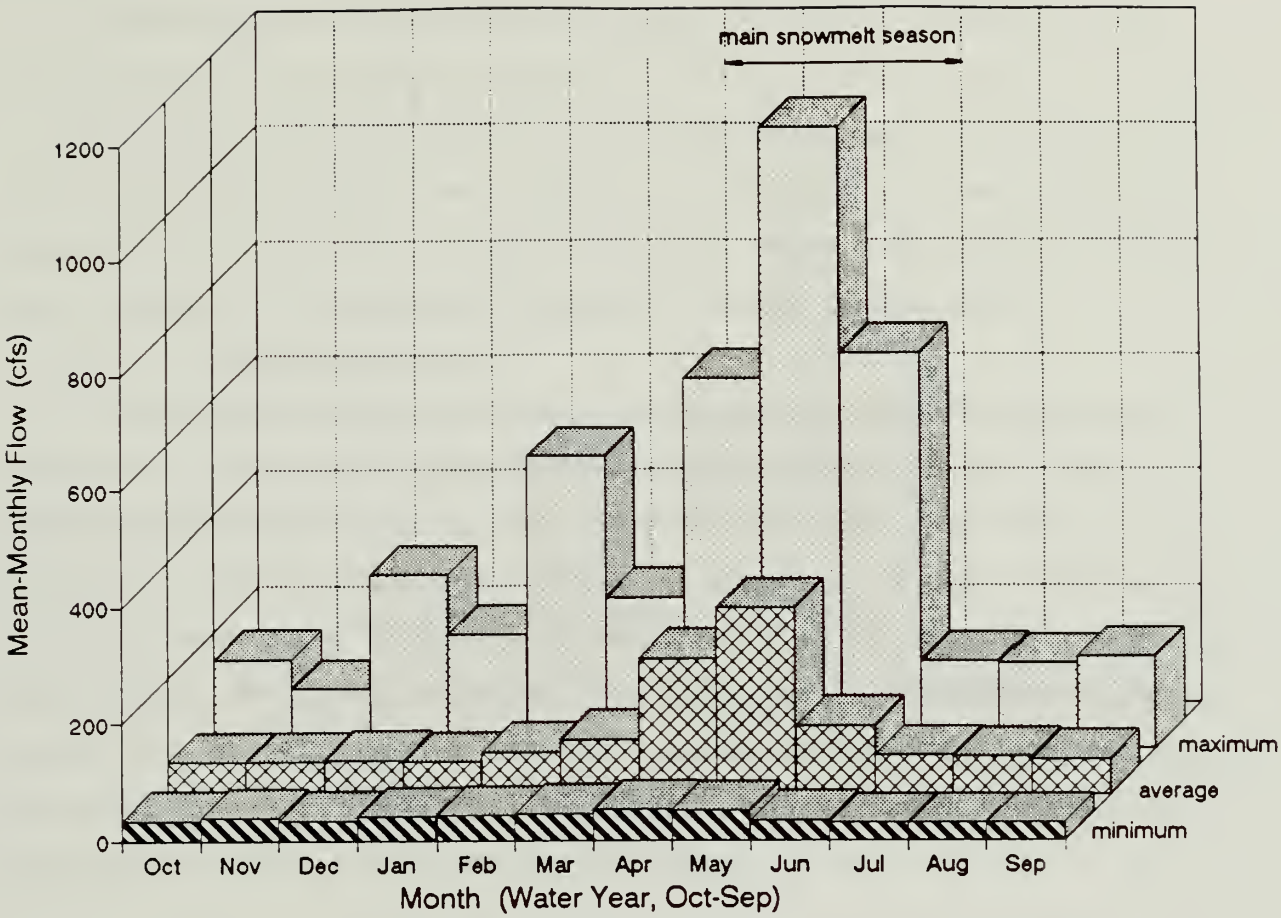

Fig. 9 Histograms of Maximum, Average, and Minimum Mean-Monthly Flows

However, as mentioned in the Section 4.1, the post-dam period received a substantial increase in precipitation (12.9%). Though the increase in discharge did not change significantly, only a 2% increase of the post- over the pro-dam period, the variability of the monthly-flows as measured by the monthly standard deviation was substantially increased, a 27% larger during the second period. In general, a more intense precipitation process will tend to increase the variance of surface runoff, whereas the presence of a reservoir in the system like Kolob Reservoir will tend to diminish it. Here there are two processes acting simultaneously and in opposite directions. If there were any decrease in flow variance due to Kolob Reservoir, it has been largely offset by the increase in variance due to the change in precipitation.

4.3 Daily Time Series

Unlike annual hydrological series, daily runoff series are non-stationary in nature. Non-stationarity is a consequence of periodicity in series parameters, which in turn, is due to the orbital rotation of the planet around the sun. Periodicity in lower-order parameters such as the mean, standard deviation, and coefficient of variation is easy to observe. But even higher-order parameters such as the skewness, kurtosis, and serial autocorelation coefficients display periodicity. A presentation of an analysis of the basic statistics follows.

4.3.1 Daily Runoff Means

The snow pack accumulated during the winter months melts mostly during April, May, and June, generating the spring peaking hydrograph shown in Figure 10. The hydrograph of estimated periodic means is composed of 365 values, from October 1st to September 30th. Each ordinate of the hydrograph is computed as the average value, during the whole period of record (1926-1988, 1927 excluded), of the daily flows obtained from the USGS database. For instance, the periodic mean for October 1st is obtained as the average value of the 62 mean-daily flows on record for that particular day. It should be mentioned that the daily flow values provided by the USGS are already the average flow for the day. Mathematically, periodic mean values are estimated by,

$$m_t = \frac{1}{n} \sum_{p=1}^{n} X_{p,t}$$

where $X_{p,t}$ represents the observed daily values, with $p = 1,2,\ldots n$ the sequence of years of record, and $t = 1,2,\ldots,w$ the sequence of days in the annual cycle of $w = 365$, and m_t the estimated periodic daily means.

The mean hydrograph during the snowmelt season shows relatively smooth rising and recession limbs, with the highest peak values in the order of 370 cfs. Outside the snowmelt season, mean-daily flow values remain relatively constant, in the order of 60 cfs. For the whole year, the hydrograph averages 104.48 cfs. However, as a consequence of intense storm events, the river peaked many times in response to runoff-producing rains. This is depicted in the graph by sharp increases in the mean-daily values.

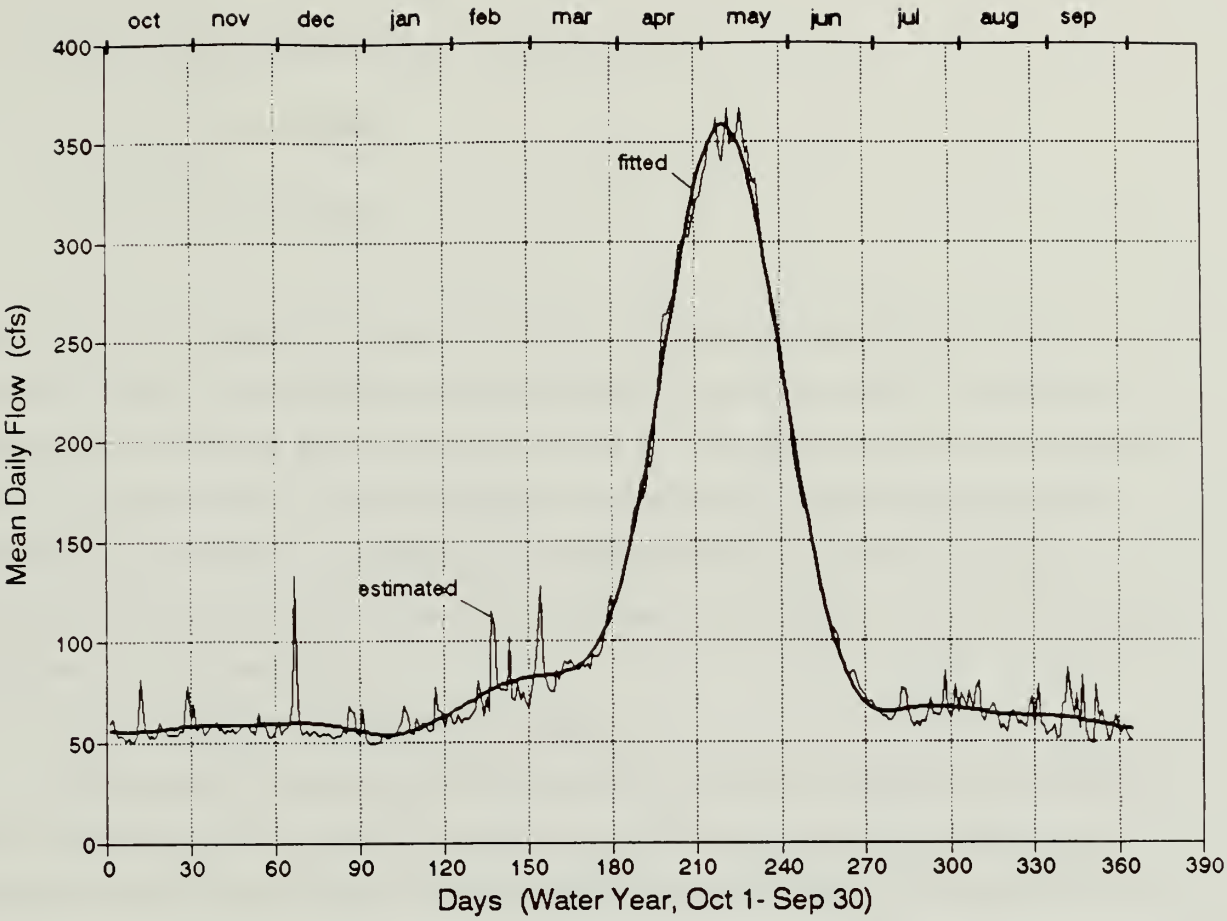

Fig.10 Periodicity in Daily Runoff Means of the NFVR at Springdale

The estimated values of a statistic always carry sampling variability because of the relatively small sample size. However, for some special applications, it may be preferable to work with a smooth representation of the estimated periodic means rather than with the sharp fluctuations of the estimated values. This is shown in Figure 10 by the darker line representing the periodic function of the daily means, fitted by Fourier series analysis. In statistical terms, the sample estimation of the statistic is being replaced by the estimate of its population value. The Fourier series representation of the periodic series is computed by the following expression,

$$v_t = m + \sum_{j=1}^{h} [A_j \cos(2\pi jt/w) + B_j \sin(2\pi jt/w)]$$

$$A_j = \frac{2}{w} \sum_{t=1}^{w} m_t \cos(\frac{2\pi jt}{w}) , \qquad j = 1,.....h$$

$$B_j = \frac{2}{w} \sum_{t=1}^{w} m_t \sin(\frac{2\pi jt}{w}) , \qquad j = 1,.....h$$

where m is the mean of m_t, and A_j and B_j are estimated coefficients, j is the harmonic, and h is the total number of harmonics. Only a few number of harmonics is required to fit daily time series, usually from 4 to 8. Although techniques are available to select the proper number of harmonics that more significantly contribute to explain the variability of the statistic, only selection by visual inspection was used in this study. Estimated and fitted values of the periodic daily mean are included at the end of this report as Appendix I an II respectively.

4.3.2 Daily Runoff Standard Deviations

The change in variance over the annual cycle results from sampling characteristics due to differences in mechanisms of producing runoff, such as runoff hydrographs from rainfall, snowmelt, groundwater or their mixtures (Yevjevich, 1984). In the NFVR, the nature of these different processes is reflected by the 365 estimates of the standard deviation of the mean-daily flows, s_t, as displayed in Figure 11, and computed according to the expression below, where all variables are as defined earlier,

$$s_t = \left[\frac{1}{n-1} \sum_{p=1}^{n} [X_{p,t} - m_t]^2 \right]^{1/2}$$

Comparing Figures 10 and 11, it can be seen that the periodicity in the mean and standard deviation of daily-flows are in phase. This is also true for higher-order parameters as shown later. Snowfall during fall and winter, and posterior snowmelt during the spring season, significantly smooth the estimates of the standard deviation from march through June. Estimates of the standard deviation during this period are, in general, of the same magnitude as the estimates of the daily means, denoted in Figure 11 as a period with

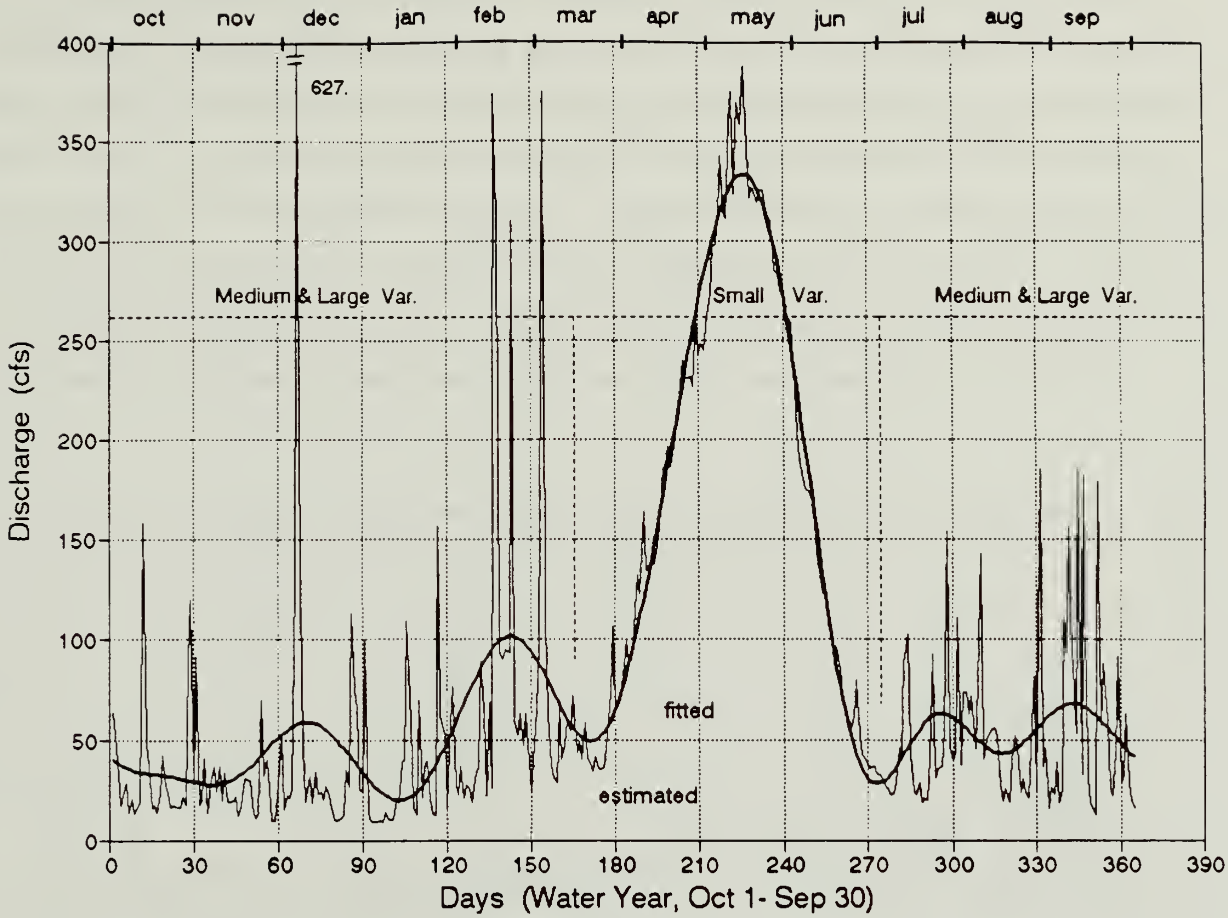

Fig.11 Periodicity in Daily Runoff Standard Deviations of the NFVR at Springdale

relatively small variance. As we depart from the snow-producing portion of the hydrograph and analyze periods of rainfall-producing runoff or their mixture snowmelt-rainfall, we find sharp spikes for the estimated values of the daily standard deviation. These deviations can double or triple the mean values (compare Figures 10 and 11, both drawn at the same scale), indicated in the graph as periods with medium and large variance. These large sampling variations are related to the fluctuations of daily flow series. The darker line in Figure 11 indicates the fitted periodic function of the standard deviation by Fourier series. Eight harmonics were used to generate the fitted function. The estimated and fitted values of the standard deviation are included in Appendix I and II respectively.

Another indicator of the degree of variability of mean-daily flows is given by the Coefficient of Variation (Cv), computed as the ratio between the standard deviation and the mean values of the daily flows. Figure 12 displays the 365 estimates of Cv, with a general mean of 0.74. Cv during the period mid-March to early July (snowmelt season) exhibits a smooth variation with most values around 1. Outside that period, Cv changes abruptly above and below the general mean, reflecting the large variability in mean-daily flows, a typical characteristic of rivers in this region. For Day 67, Cv reaches the maximum value of 4.71 (not shown). This peak is associated with the maximum mean-daily flow of 4,990 cfs.

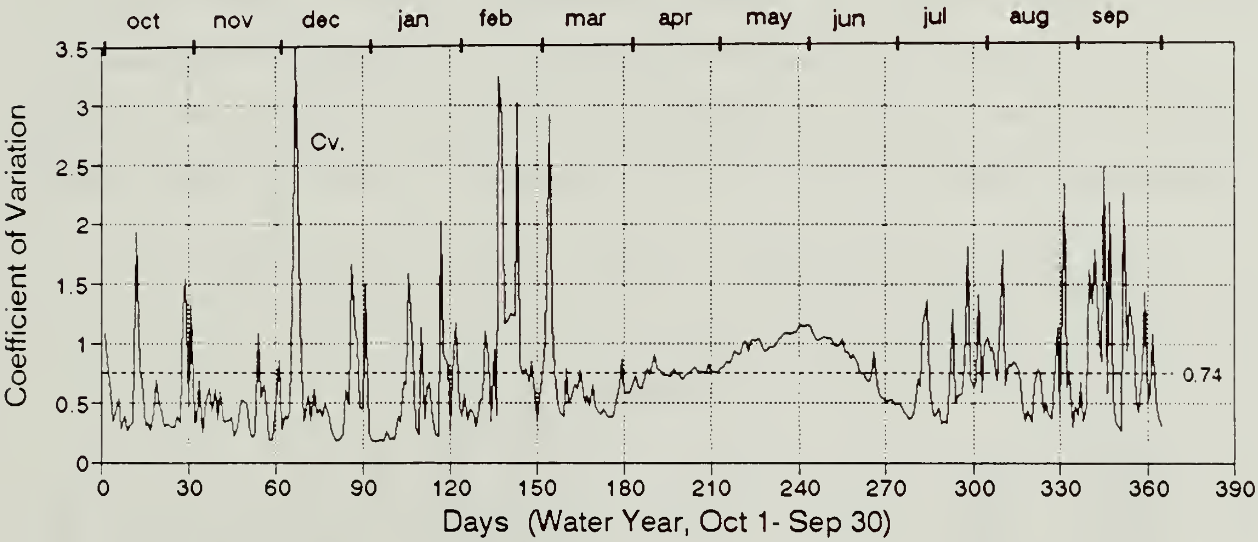

Fig.12 Periodic Estimates of Coefficient of Variation of the NFVR at Springdale

4.3.3 Higher Order Statistics of Daily Runoff

In principle, there are 365 probability distributions and 365 sequential dependence functions in the daily-flow series, one for each of the 365 days of the annual cycle (Yevjevich, 1984). These distributions and dependence functions can vary from day to day throughout the year. Determination of the most suitable probability function for each marginal distribution is beyond the scope of this study. Nevertheless, basic parameters like the arithmetic mean and standard deviation of the daily-flows give us a good indication of the

shape of the distributions. More yet, we can better describe the shape of the marginal distributions by computing higher-order parameters, like the Skewness coefficient, g_t , and the Kurtosis coefficient, k_t . The two parameters g_t and k_t are estimated by the expressions

$$g_t = \sum_{p=1}^{n} \frac{[X_{p,t} - m_t]^3}{n\, s_t^3}$$

and

$$k_t = \sum_{p=1}^{n} \frac{[X_{p,t} - m_t]^4}{n\, s_t^4}$$

respectively, where m_t and s_t were previously defined. The skewness coefficient provides a measure of the "asymmetry" of the distribution, independent of the dimension of the variable. Due to large sampling variations characteristic of short-time interval series, high skewness values are typical for mean-daily runoff series. Figure 13 displays high positive

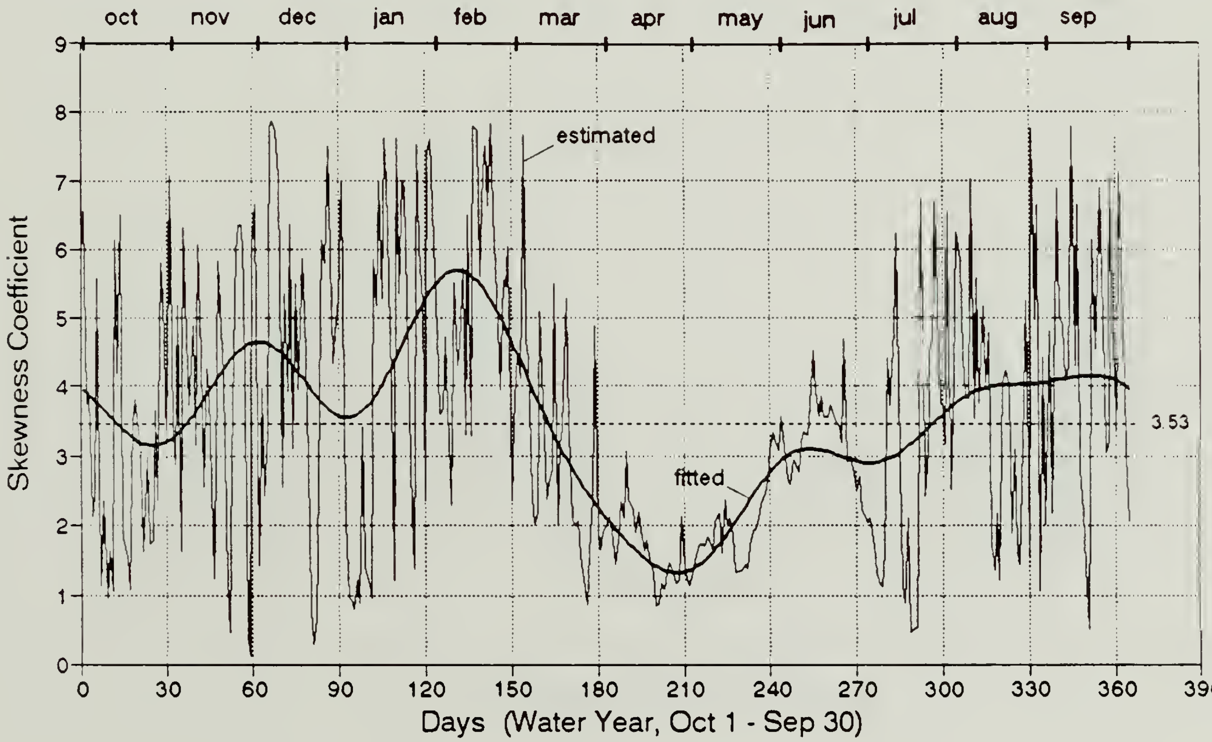

Fig.13 Daily Coefficient of Skewness of the NFVR at Springdale

skewness values for the daily-flows at Springdale, with an average value of 3.5, indicating highly asymmetric marginal distributions. For comparison, a normal distribution has a value of skewness equal to zero. The smooth fitted line helps to visualize the results, showing closer to normal distributions during the snowmelt season, and highly positively skewed distributions during the rest of the year.

The Kurtosis coefficient provides a measure of the "flatness" or "peakedness" of the marginal distributions, also independent of the dimension of the variable. Figure 14 displays the 365 estimated Kurtosis coefficients with an annual average value of 21.6. The estimated values of k_t for most of the days of the year are much higher than k=3, value that corresponds to a normal distribution. These large values imply that practically all marginal distributions have sharper peaks than the normal distribution. The smooth fitted curve also shown in Figure 14 indicates that the Skewness and Kurtosis coefficients are mutually in phase in their periodicities, displaying smaller values during the snowmelt season (closer to

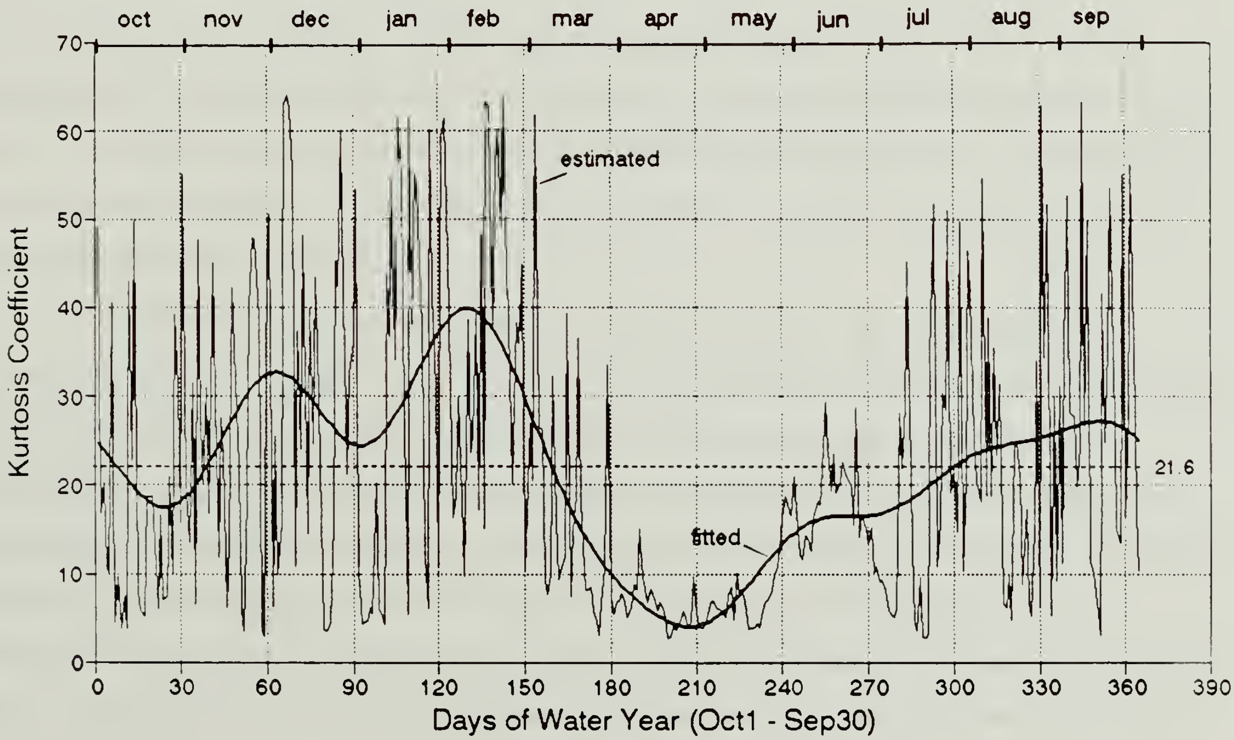

Fig.14 Daily Coefficients of Kurtosis of the NFVR at Springdale

normality), and higher values for the rest of the year.

4.3.4. Correlation in Time of Daily Flows

Daily flows have a strong dependence in time of successive values. The dependence structure is a result of several complex physical processes. It is principally governed by the way the basin responds to precipitation when generating excess rainfall, the manner that groundwater reaches the stream, and the river itself, that transports the runoff. Periodicity can also be detected in the dependance structure of daily flows. According to the time of the year, the basin reacts differently to the excitation, which can be rainfall, snowmelt, or a combination of the two. The linear dependence of daily flows can be measured by the k^{th} correlation coefficient r_k, where k indicates the lag (in days) to measure the degree of association between flow values. Mathematically, it is computed by the expression,

$$r_k = \frac{cov(X_{p,t}\ ,\ X_{p,t+k})}{(var\,X_{p,t}\ .\ var\,X_{p,t+k})^{1/2}}$$

where ***var*** and ***cov*** denote the variance and covariance respectively of the flow variable, represented in the equation by X. The coefficients r_k can adopt values in the range +1 to -1, with "1" showing perfect correlation and "0" absolute lack of association. The dependence structure of the NFVR at Springdale is shown in Figure 15, for k=1, named the periodic first autocorrelation coefficient.

Notice, Figure 15, that during those months of the year with very high flow variability, October through March and July through September, the time correlation between daily flows is also quite variable, with ordinates that can even drop to zero (totally uncorrelated flows). This should be expected since rainfall events drastically reduce the autocovariance between daily flows, and at the same time, increase the variance. Contrarily, during the period of the year when snowmelt is the major runoff contributor, the autocorrelation reaches values close to 1, that is, during that time of the year, the mean-daily flow at any given day can be quite precisely estimated based on the flow level that occurred during the previous day. The periodic function computed by Fourier series and shown in Figure 15 with a darker line helps visualize the dependence structure just described.

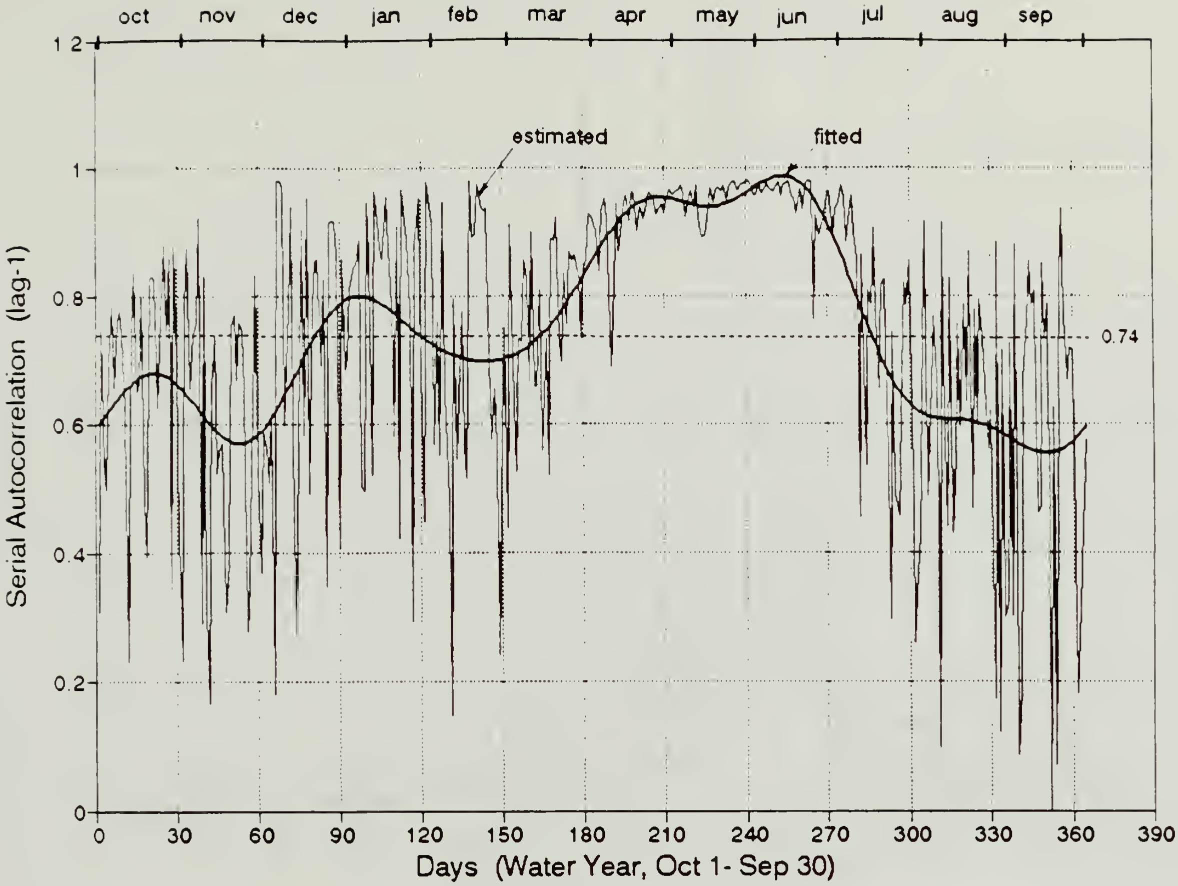

Fig.15 First Autocorrelation Coefficient of NFVR at Springdale

4.3.5 Typical Water Years

Finally, after having analyzed the structure of flows at the daily time interval, it is illustrative to show the distribution of mean-daily flows not as average conditions for the period of record, but as the actual series of daily flows for a few specific years. A very dry water-year (1960), a normal year (1965), and a very wet year (1941) were selected and plotted in Figure 16. These years can be considered typical of most water years of record in each category.

The portion of the hydrograph characteristic of the snowmelt season can be seen in all three hydrographs, though it is much less pronounced as we move from the wettest to the

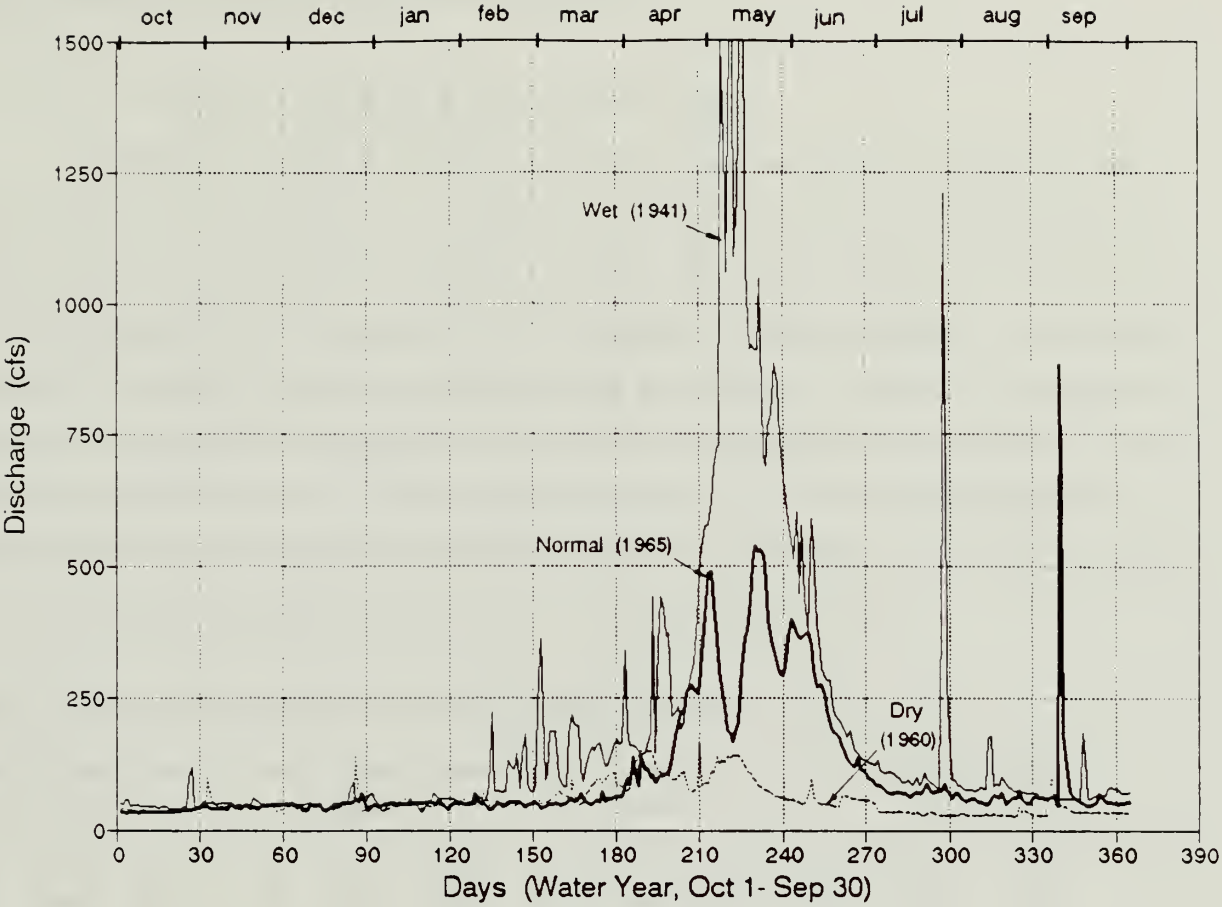

Fig.16 Typical Wet, Normal, and Dry Water Years of the NFVR at Springdale.

driest year. Base flow remains practically constant during the months of October through February, around 50 to 60 cfs, for the three years. In fact, base flow remains within that range of values year after year for the whole period of record, regardless of how wet or dry the hydrologic year was. Even during the critical period of 1974-1977, affected by a severe shortage in precipitation, the base flow remained close to 60 cfs. The hydrographs also show sudden increases in flows as a result of runoff-producing rainfall during the summer season.

5.0 FLOW FREQUENCY ANALYSIS

5.1 Frequency Analysis of Annual Peak Flows

A hydrologic variable of importance dominating the analysis of channel processes is the distribution of flood events. Customarily, flows start to be considered floods when the water stages in the river reach bank level on the alluvial channel. Floods are responsible for the abrupt modification of the geometry and composition of alluvial channels. The greatest quantity of substratum is moved during these large flow events, The area of hydrology that analyzes the magnitude and frequency of occurrence of extraordinary flow events is known as flood frequency analysis. Flood frequency analysis for the NFVR at Springdale was derived from the annual series of instantaneous peak flows provided by the USGS, a total of 65 values (discontinuous record from 1913 to 1988), as listed in Table 4.

Table 4. Instantaneous Peak Flows of the NFVR at Springdale, (flows in cfs)

Rank	Annual Series	Water Yr	Rank	Annual Series	Water Yr	Rank	Annual Series	Water Yr	Rank	Annual Series	Water Yr
1	9150	1967	18	680	1950	35	1690	1945	52	940	1934
2	7000	1938	19	2540	1937	36	1670	1979	53	920	1913
3	5990	1965	20	2520	1952	37	1660	1953	54	833	1951
4	5880	1961	21	2500	1932	38	1620	1966	55	798	1948
5	4480	1936	22	2490	1983	39	1580	1988	56	776	1974
6	4340	1963	23	2480	1954	40	1460	1914	57	750	1928
7	4140	1975	24	2390	1971	41	1370	1944	58	749	1977
8	4110	1940	25	2370	1931	42	1350	1964	59	734	1943
9	3960	1955	26	2270	1958	43	1350	1970	60	710	1926
10	3900	1929	27	2200	1972	44	1325	1978	61	668	1957
11	3880	1969	28	2190	1981	45	1240	1976	62	610	1986
12	3520	1947	29	2090	1984	46	1200	1927	63	558	1946
13	3190	1980	30	2070	1959	47	1180	1942	64	430	1960
14	3100	1941	31	1980	1935	48	1100	1949	65	428	1930
15	3000	1933	32	1970	1973	49	1050	1985			
16	2900	1939	33	1930	1968	50	1010	1987			
17	2780	1982	34	1870	1962	51	956	1956			

Peak flows should not be confused with the maximum annual discharges plotted at the top of Figure 7. The latter are average values for the day and not instantaneous flow values.

For instance, the maximum mean-daily discharge on record for December 6th, 1966 (corresponding to water-year 1967), was 4990 cfs. For that same day, the peak discharge registered was almost twice that value, 9150 cfs.

Several extreme value distributions were tried to fit the empirical frequency of floods at the Springdale station, they are: the Gumbel distribution, the Log-Pearson Type III distribution recommended by the U.S Water Resources Council (1982), the Log-Normal distribution, and the Exponential distribution. All fitted distributions are shown in Figure 17. Practically all distributions reflect the same rate of occurrence for floods up to a magnitude of 5000 cfs. Above that flood level, significant differences are found among the four functions. The numbers in parenthesis in Figure 17 denote the standard error associated with each distribution, a quantitative measure of the goodness of fit.

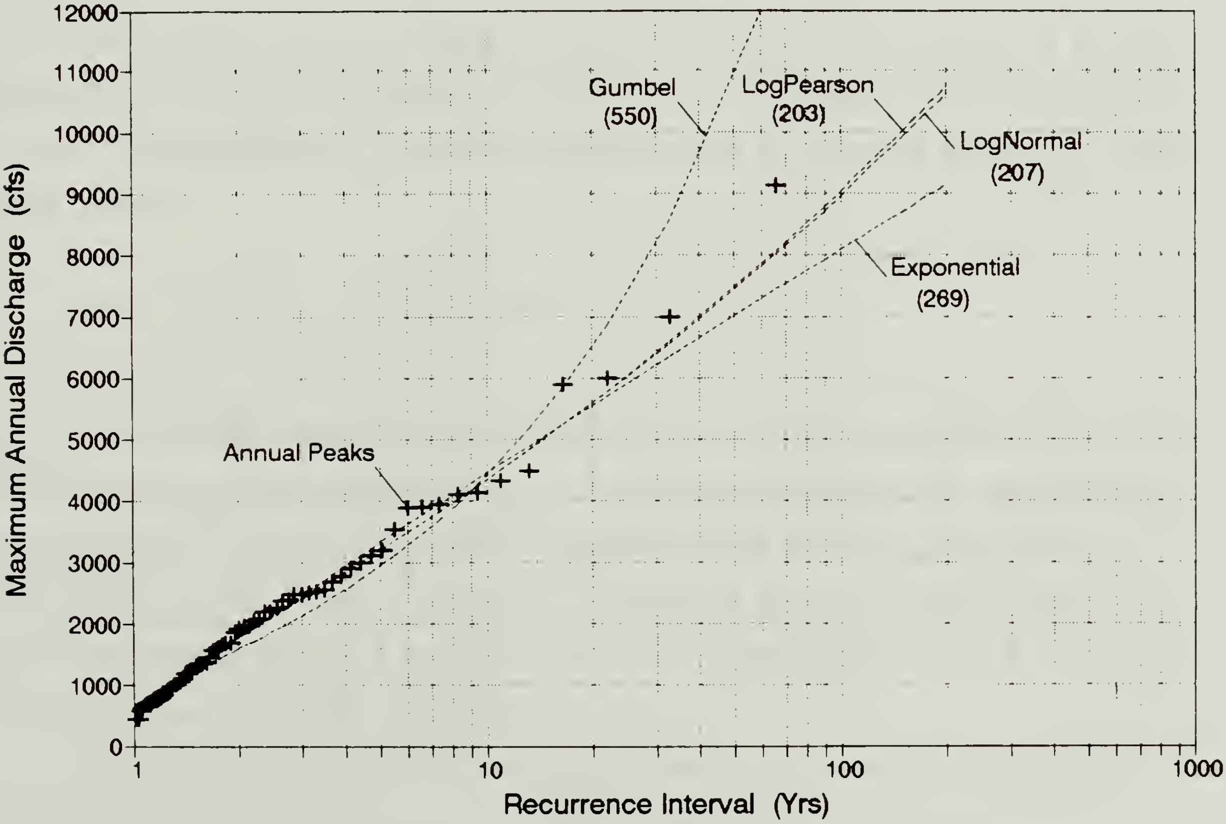

Fig.17 Flood Frequency Distributions of Annual Peaks of the NFVR at Springdale

The Log-Pearson type III and the Log-Normal distributions turned out equally suitable for representing floods at the Springdale station. Similar fitting by these two distributions should be expected since the Virgin River is located in a region of the country where the generalized skew coefficient (estimated by the USGS) is practically zero. That finding was corroborated during this study. As the skewness coefficient decreases, the Log-Pearson Type III distribution converges toward the Log-Normal distribution.

Based on the results shown in Figure 17, the Log-Pearson Type III distribution was adopted to model the annual maxima streamflow series at Springdale. The T-Year event magnitude (in the base 10 log-domain) can be computed from the general equation

$$X_T = \bar{X} + K_T\, S$$

where $\bar{X}$ and S are sample estimates of the population mean and standard deviation of the peak flows available (also in the log domain). The frequency factor K_T, specific to the Log Pearson distribution, can be obtained from tables (U.S. Water Resources Council, 1982), or it can be approximated by the following expression when the skewness is between -1 and +1 (Bras, 1990),

$$K_T = \frac{2}{G_w}\left\langle\left[\left(t_{1-p} - \frac{G_w}{6}\right)\frac{G_w}{6} + 1\right]^3 - 1\right\rangle$$

where G_w is the generalized skewness coefficient of the peak flows available, and t_{1-p} is the standard normal deviate corresponding to a p exceedance probability (or equivalently of return period T). The first three sample moments of peak flows at Springdale are: $\bar{X}$=7.4876, S=0.6935, and G_w=0.0147. Furthermore, moment estimates of the scale, shape, and location parameters for the Log Pearson type III distribution yield α=0.0051, β=18542.1, and γ=-86.95, respectively.

Unfortunately, the estimated value of peak flows of large return period are likely to be in error. The relatively small size of the floods sample can bias the selection of the distribution. Bias may also be due to inaccuracies in the estimation of the parameters of the distribution. In order to account for those possible sources of errors, Figure 18 shows the

fitted Log Pearson distribution of the annual peaks and places confidence limits on the estimated flood values.

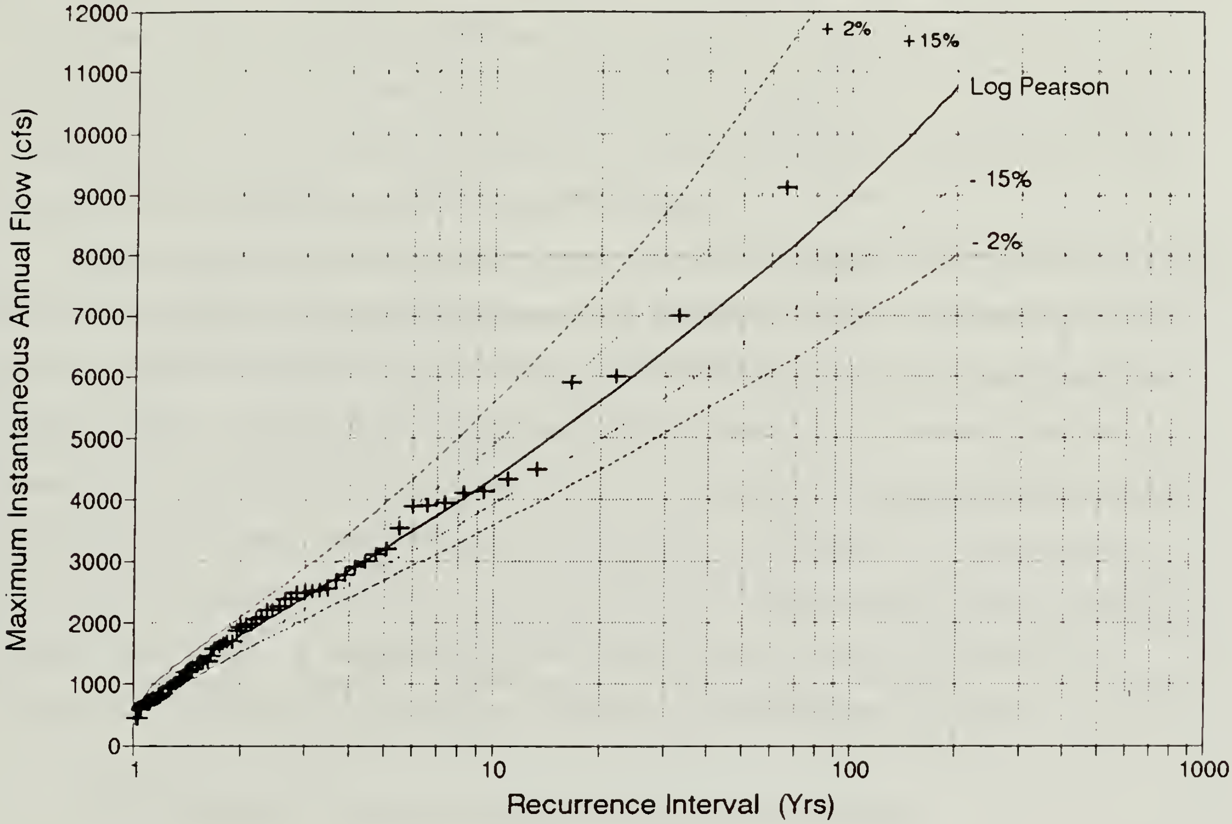

Fig.18 Fitted Distribution and Confidence Limits of Annual Peaks

The general mathematical expression to compute confidence limits for a given recurrence interval T is

$$X_T^{c.l.} = \bar{X} \pm K_C\, S$$

where the upper limit is computed using the (+) sign, and the lower bound with the (-) sign. For the case of the Virgin River, where $G_w \approx 0$, the factor K_C can be approximated by

$$K_C = t_{1-p} + \left[1 + 0.5\,(t_{1-p})^2\right]^{1/2} \frac{t_{1-\alpha}^{N-1}}{\sqrt{N}}$$

where N is the sample size and $t_{1-\alpha}$ denotes the standard normal deviate at the α one-sided level of significance. Upper and lower confidence limits at the 2% and 15% levels of significance are shown in Figure 18 as examples. The upper and lower bounds imply that, for instance, when considering confidence limits at the α=2% level of significance, the probability that any future flood event will lay within the range [+2%, -2%] is equal to (100-2-2)= 96%, or vice versa, that there is a 4% probability that an extraordinary flow event will not be contained within the specified bounds.

Notice that the maximum flood on record, 9150 cfs, appears to depart from the trend of the data. However, the departure is not large enough to consider that particular flood event an "outlier" according to the criterion recommended by the U.S. Water Resources Council (1982). It should also be mentioned that the present flood frequency analysis assumed that all flood events are caused by the same runoff-producing mechanism, without distinguishing between floods due to precipitation only, which generally occur during summer, and those due to snowmelt or a combination of snowmelt and rainfall, which occur in winter and spring. If necessary, the two types of flood events can be treated as components of different populations for independent flood frequency analyses.

5.2 Frequency Analysis of High and Low Flow Variables

Time series of high and low flows variables can be computed for various time intervals, for instance: 1-day, 3-day, 7-day, 30-day, and 90-days overlapping sub-sequences from the complete sequence of daily flows. Depending on the purpose of the application at hand, different time intervals may be useful. The procedure for the computation of any one of these variables is simple. Based on the time series of historic mean-daily flows, a sequence of the selected high- or low-flow variable is created, providing a new random variable which has a distribution and may have a time dependence as well. The new high/low-flow variable is expressed as the average discharge for the selected interval. The distribution of the high/low-flow time series can be approximated by the empirical frequency distribution of the sequence, which in turn, can be fitted by a probability distribution if necessary. This empirical approach circumvents to a large degree the difficulties encountered in the theoretical analysis of low-flow variables, due to their large dependence

and periodicity. Figure 19 and 20 display the family of curves for high- and low-flows, respectively, for the durations indicated above. Details of the origin of the curves at a more readable scale are also shown.

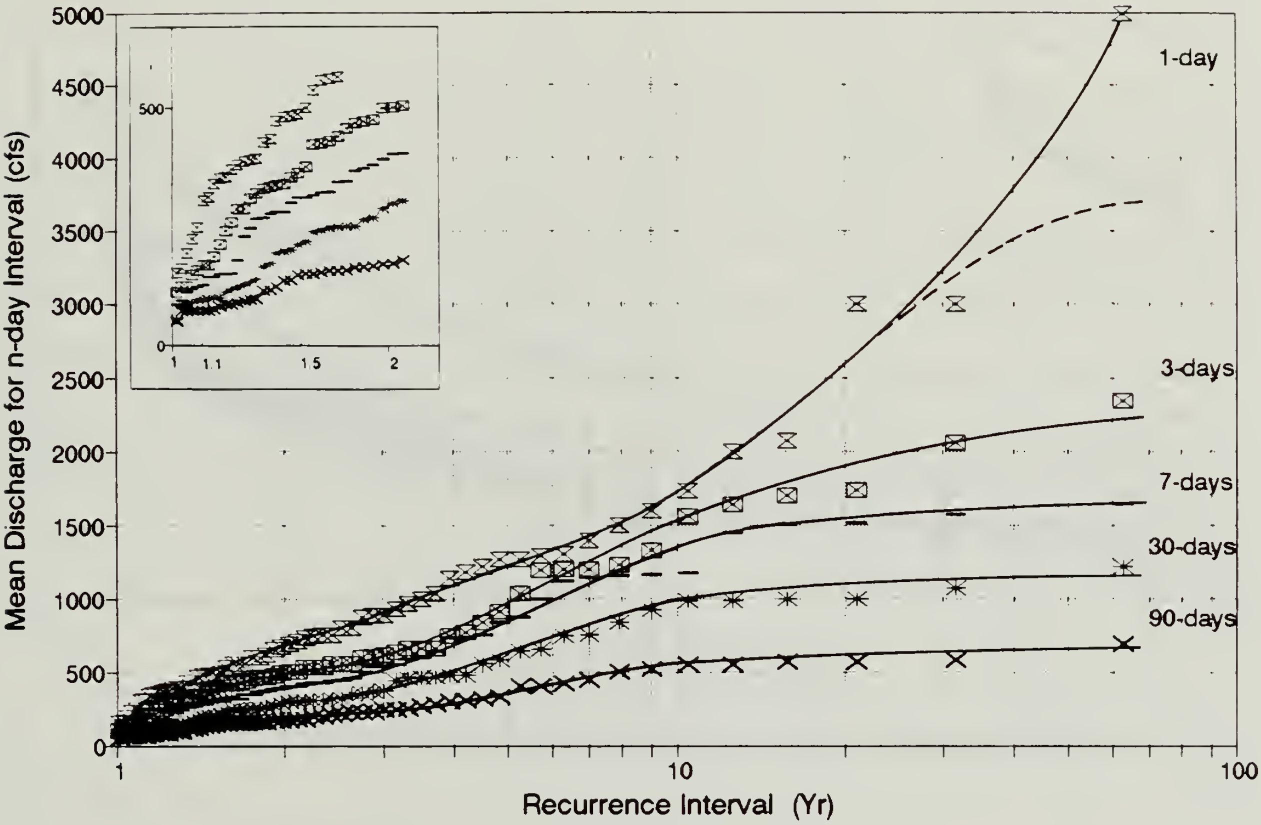

Fig.19 High-Flows Frequency Curves For Various Consecutive Days

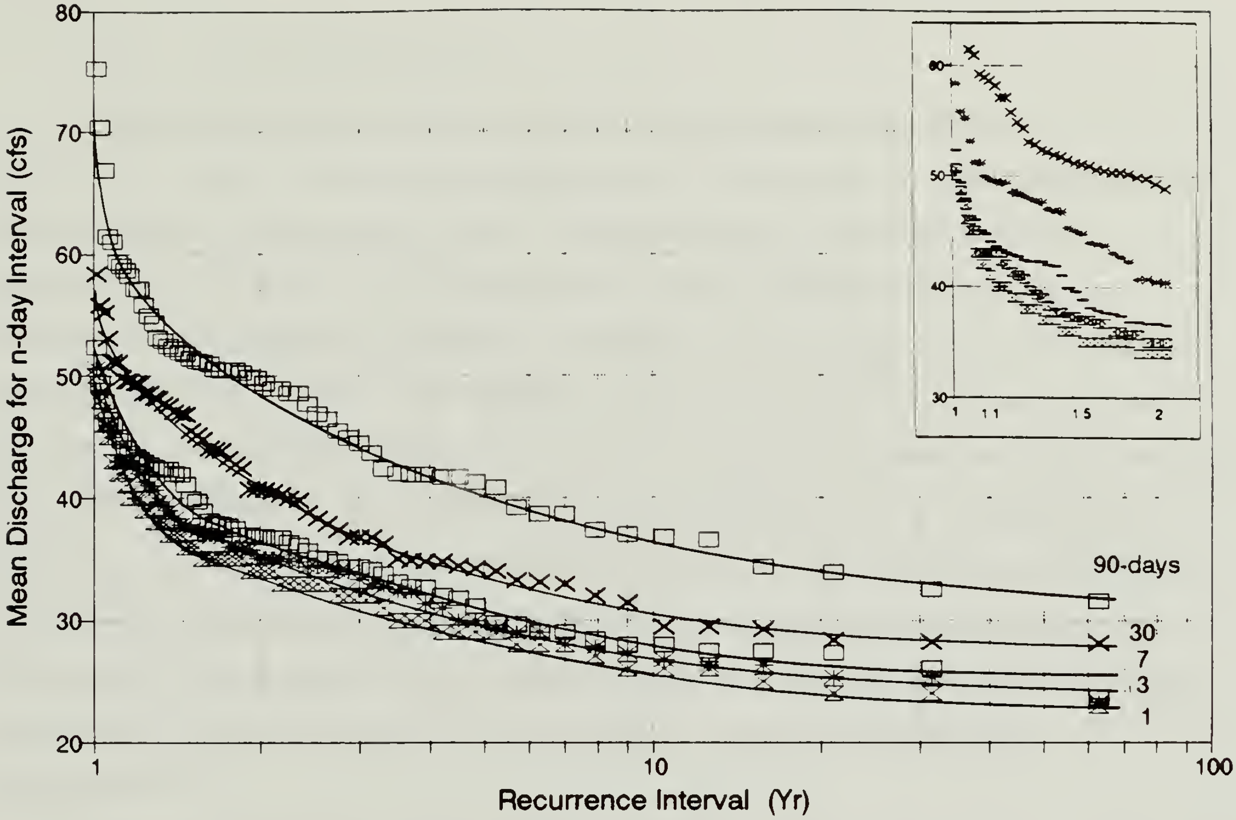

Fig.20 Low-Flows Frequency Curves For Various Consecutive Days

6.0 FLOW DURATION ANALYSIS

6.1 At a Gaged River Site

Flow duration analysis (FDA) estimates the percentage of time values of a given flow time series are above or below a certain flow level. FDA provides a sense of the variability of flows during a given time span, which it can range from a multi-year period to a particular month or season. The duration curve resulting from the FDA is useful in predicting the availability and variability of sustained flows, although it does not represent the actual sequence of flows. Flow duration curves can readily be constructed from the historical flow records at gaged points in a river. A potential application of FDA in the Zion area is the comparison of natural (existing) and post-impoundment (via simulation) flow regimes at reaches of the river downstream from sites where the construction of reservoirs with capacity to regulate flows are under consideration. Moreover, with the advent of environmental considerations in river systems management, flow duration information can also be used to predict changes in river morphology, changes in biological river communities, etc.

The shorter the length of the averaging time (observation period) used to construct the flow series, the more accurate the information embedded in the flow duration curve. The use of flow series at short time intervals is particularly important for rivers with flashy flow regimes like the NFVR, susceptible to fast rising and falling of its runoff hydrographs. Based on the flow data available for the NFVR, daily flows will provide the most accurate duration curves. The computation of duration curves utilizing discrete flows for coarser time intervals (weekly or monthly) would produce the undesirable effect of concealing the important extreme flows (maximum and minimum values) because of the averaging of daily flow data. The present analysis is based on the complete series of mean-daily flows for the NFVR at the Springdale Station during the period 1926-1988. Results of the FDA are presented in Table 5, which contains the ordinates of the flow duration curve for integer numbers of exceedance percentages. The flow duration curve is plotted in Figure 21, which displays the same flow duration curve in double logarithmic scales and in the natural domain.

Table 5. Values of the Flow Duration Curve at Springdale

Exc. (%)	Flow (cfs)	Exc. (%)	Flow (cfs)	Exc. (%)	Flow (cfs)	Exc. (%)	Flow (cfs)	Exc. (%)	Flow (cfs)
≈0	4990.								
1	828.	21	98	41	64.	61	54.	81	44.
2	618.	22	93.	42	64.	62	53.	82	44.
3	498.	23	90.	43	63.	63	53.	83	43.
4	411.	24	87.	44	62.	64	52.	84	43.
5	350.	25	85.	45	62.	65	52.	85	42.
6	306.	26	82.	46	61.	66	51.	86	42.
7	276.	27	80.	47	60.	67	51.	87	41.
8	247.	28	78.	48	60.	68	50.	88	41.
9	220.	29	76.	49	60.	69	50.	89	40.
10	197.	30	75.	50	59.	70	50.	90	40.
11	181.	31	74.	51	58.	71	49.	91	39.
12	165.	32	73.	52	58.	72	49.	92	38.
13	151.	33	72.	53	57.	73	49.	93	37.
14	142.	34	70.	54	57.	74	48.	94	37.
15	133.	35	69.	55	56.	75	48.	95	36.
16	125.	36	68.	56	56.	76	47.	96	35.
17	118.	37	67.	57	55.	77	46.	97	34.
18	113.	38	66.	58	55.	78	46.	98	32.
19	107.	39	66.	59	54.	79	45.	99	29.
20	102.	40	65.	60	54.	80	45.	100	23.

Rivers in the Zion region display a singular shape of the flow duration curve. Instead of the more standard S-shaped curve of flow versus exceedance percentage, the duration curve at Springdale (see plotting in the natural scale) has more the shape of an equilateral hyperbola, with both limbs running practically parallel to the horizontal and vertical axes. The sharply descending vertical limb of the duration curve in the 1% to 6% exceedance percent range indicates that flows higher than 300 cfs have a very low probability of occurrence. Contrarily, flows smaller than 100 cfs occur almost 80% of the time. The slowly descending horizontal limb of the duration curve lies within a relatively narrow flow range, between 100 and 40 cfs, and occupying a wide range of exceedance probabilities, between 20% and 90%. That indicates the large persistence of flows under 100 cfs. The flow volume represented by the area under the flow duration curve was computed by graphical integration. The value obtained, 77,620. Ac-Ft, is reasonably close (2.5% difference) to the historical mean annual flow of 75,718. Ac-Ft indicated in Table 3, Site (12).

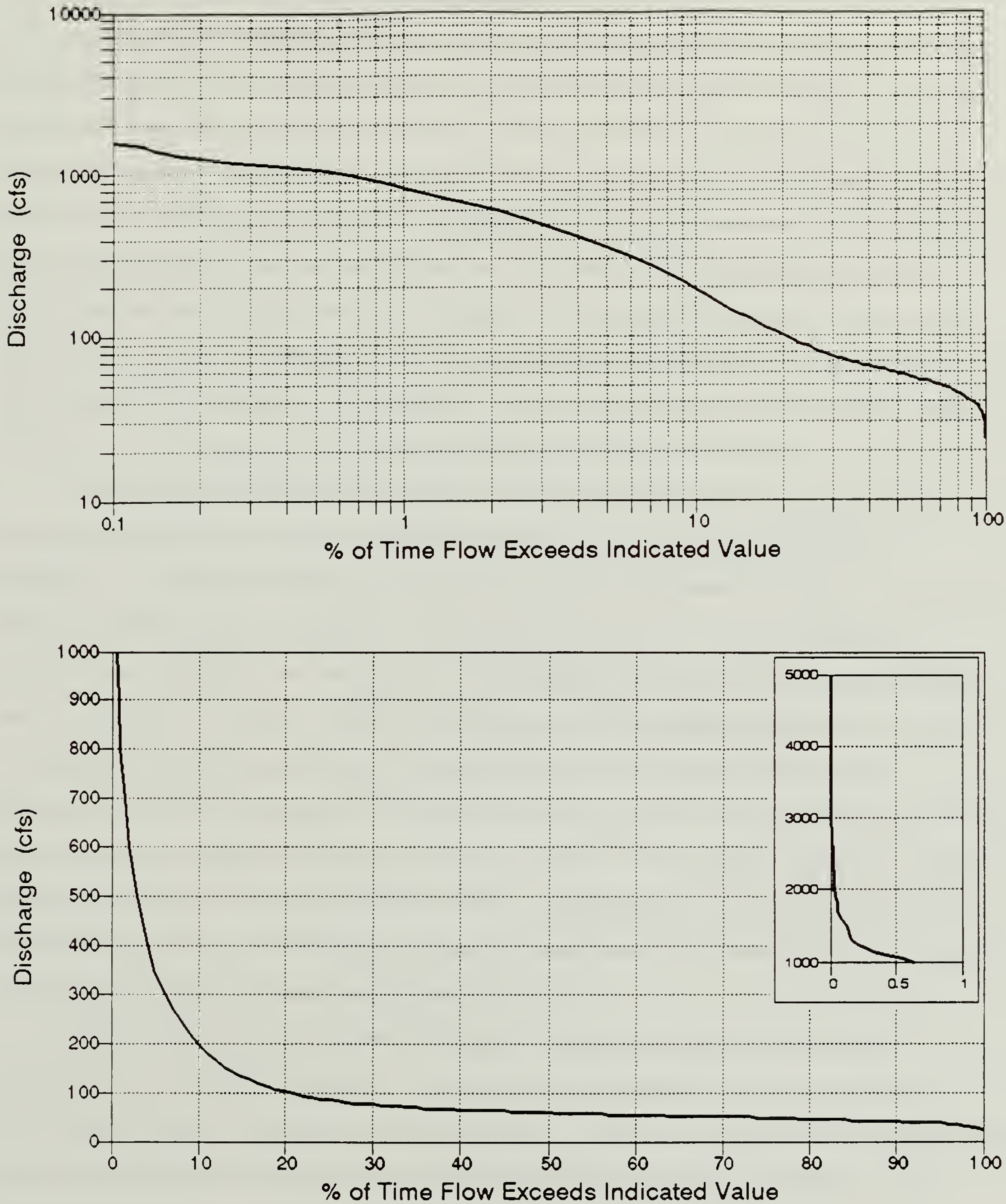

Fig.21 Flow Duration Curve of the NFVR at Springdale
Top: Logarithmic Scales, Bottom: Natural Scales

6.2 Parametric Flow Duration Analysis

As part of the methodology under implementation for quantifying federal water rights at Zion National Park, it will be required to define flows and their corresponding durations at several locations inside and outside the Park. More specifically, these locations include: reaches where the main water courses enter the Park (also known as quantification points), specific study sites within the Park where biological and channel processes studies are being conducted, and other locations outside the Park with the purpose of supporting reservoir operational studies. Unfortunately, as it happens in any real world project, sites at which hydrologic information is required very rarely coincide with the locations at which flows are being recorded systematically. The number of gaging stations in the Zion region is limited, see Table 3 and Figure 4, and sometimes with very short period of record.

The procedure presented in this section attempts to circumvent this problem by investigating potential correlative associations between parameters representing flow variability at a specific location with some other readily identifiable flow statistic at the same site, for instance, mean annual flow. If such relationships exist, it will be possible to estimate flow availability and variability at any ungaged site provided that annual discharge can be computed. The basic underlying assumption of the suggested approach is that in a "homogeneous" hydrologic region, the complex physical processes controlling flow variability affect the whole region in a similar manner. In other words, the shape of the flow duration curve at different locations in a river, or even the flow duration curves for different streams in a region, will remain similar in shape. This approach, if proved acceptable, can be particularly useful in the Zion area, where for some streams, streamflow does not to vary in direct proportion to the contributing drainage area.

The flow duration curve shown in Figure 21 was constructed using flow data corresponding to a specific location on the NFVR (at Springdale) and, consequently, it reflects the variability of flows at that particular site. Similar computations can be performed at all those locations in the Zion region where reliable flow records are available. The gaging stations in the Zion area used for this study were chosen according to the following selection criteria:

- ☞ stations with the longest and more reliable period of record, preferably with not less than 6 years of records,
- ☞ stations with unregulated flows and with none or moderate water diversions upstream from the gaging station,
- ☞ stations conveying hydrological information from the heads, intermediate reaches, and the mouths of the basins,
- ☞ stations covering the widest possible range of mean annual flows, and
- ☞ stations within the same (homogeneous) hydrologic region.

Only half of the stations listed in Table 2 partially satisfied the selection criteria above. The chosen stations are listed in Table 6.

Table 6. Selected Gaging Stations for Parametric FDA

Site	Station No.	Station Name
(1)	09403600	Kanab Creek Near Kanab
(2)	09404450	East Fork Virgin River near Glendale
(4)	09405200	Deep Creek Near Cedar City
(7)	09405400	North Fork Virgin River Near Glendale
(8)	09405420	North Fork Virgin River Below Bullock Canyon
(9)	09405450	North Fork Virgin River Above Zion Narrows
(12)	09405500	North Fork Virgin River Near Springdale
(15)	09406000	Virgin River at Virgin

Not all the selection criteria could be met at the same time because of the limited number of gaging stations in the Zion area . For instance, the station at Site (4), although it has a period of record shorter than 6 years, was included in Table 6 because it is expected to provide valuable information about flow variability in relatively small and high altitude watersheds. Quantification points located in headwater areas with no flow records available, as in the case of La Verkin Creek, should benefit from the information provided by Site (4). However, the sequence of stations at Sites (7), (8), (9), and (12), all located over the same stream, the NFVR, will provide the opportunity to corroborate the assumption that there is a definite pattern in flow variability as mean annual flow increases downstream. Stations on different basins like those at Sites (1), (2) and (15) were purposely included in Table 6 to

test the hypothesis that a similar pattern in flow variability extends to other sub-areas as well, provided that they are all located in a region with homogeneous hydrological characteristics.

The station at Site (1), in Kanab Creek, although it is not part of the Upper Basin of the Virgin River, should be considered part of the same hydrologic region. Kanab Creek is located in the basin east of the EFVR. Both basins have similar shape and geographic orientation, and the gaging station at Kanab Creek is located at approximately the same elevation as the NPS study site in the EFVR, near Site (3). Stations at Sites (5), (6), (14) and (16) were excluded from the analysis not only because of the short period of record, but also because the majority of the water years during the period of record were noticeably dry. Stations at Sites (3) and (10) were only very recently installed.

In summary, the selected eight stations cover a wide range of drainage areas and water yield as required. They range from the relatively small watershed at Site (4) in the high country, to the station in the valley floor at Site (15), which encompasses the largest contributing drainage area under analysis, an area almost 140 times larger than the one at Site (4), and with a water yield over 120 times.

Ordinates of the flow duration curves corresponding to the selected stations are tabulated in the upper portion of Table 7. Flows (in cfs) are expressed in a base-10 logarithmic scale. A whole range of exceedance probabilities is provided in order to fully define the shape of a typical flow duration curve. Next, flows corresponding to exceedance percentages equal to 1, 3, 7, 20, 30, 70, and 90% for each station were plotted against the corresponding mean annual discharge (in Ac-Ft) on a double logarithmic scale as shown in Figure 22. The sub-set of exceedance percentages was arbitrarily chosen for the purpose of the illustration. As depicted by Figure 22, the hypothesis that the pattern of flow variability is preserved among stations as a function of the mean annual discharge is confirmed by the strong linear correlation between the two variables. From the statistical point of view, we are looking for associative relationships between two random variables, flow at a given percentage exceedance level, and mean annual discharge, both having the same causative factor, precipitation in the basin.

Table 7. Flow Values for Duration Curves at Selected Sites

USGS No.	Annual Flow (Ac-Ft)	Flows (in cfs) for Probabilities of Exceedance (in %) equal to: 1	3	7	10	20	30	40	50	60	70	80	90	95	99
09403600	4.0240	1.9731	1.7076	1.4314	1.3263	1.2041	1.1461	1.0792	1.0414	0.9685	0.9138	0.8573	0.7782	0.6990	0.5682
09404450	4.1466	2.1173	1.7723	1.5051	1.4314	1.3424	1.2788	1.2304	1.1761	0.1271	1.0792	1.0414	0.9243	0.8062	0.6902
09405200	3.0745	0.9294	0.7404	0.5563	0.4914	0.3424	0.2304	0.1761	0.1139	0.0000	-0.0969	-0.2218	-0.3979	-0.5229	-0.6990
09405400	3.5592	1.4150	1.2380	1.0792	0.9956	0.8921	0.7324	0.6021	0.5185	0.4624	0.4150	0.3424	0.0792	-0.0969	-0.3010
09405420	4.1555	2.0414	1.8543	1.6532	1.5441	1.3979	1.3010	1.2553	1.1761	1.1139	1.0000	0.9243	0.8195	0.7559	0.5911
09405450	4.2683	2.0983	2.0000	1.7896	1.6902	1.4624	1.3979	1.3222	1.2788	1.2304	1.1461	1.0792	0.9542	0.8865	0.7853
09405500	4.8792	2.9179	2.6972	2.4409	2.2945	2.0086	1.8751	1.8129	1.7709	1.7324	1.6990	1.6532	1.6021	1.5563	1.4624
09406000	5.1651	3.1072	2.8993	2.6875	2.5877	2.3522	2.2330	2.1614	2.1139	2.0682	2.0170	1.9494	1.8513	1.7782	1.6721

Regression Analysis

	1	3	7	10	20	30	40	50	60	70	80	90	95	99
Intercept ***a*** :	-2.3560	-2.5313	-2.6387	-2.6281	-2.4946	-2.5997	-2.6984	-2.8095	-2.9897	-3.1327	-3.3074	-3.7192	-4.0002	-4.3352
Slope ***b*** :	1.0654	1.0567	1.0295	1.0034	0.9305	0.9315	0.9385	0.9517	0.9804	0.9989	1.0244	1.0929	1 .1380	1.1857
R-square:	0.9937	0.9961	0.9911	0.9923	0.9953	0.9968	0.9959	0.9959	0.9964	0.9971	0.9941	0.9898	0.9863	0.9817
Std Err Y:	0.0608	0.0472	0.0701	0.0636	0.0461	0.0377	0.0432	0.0434	0.0425	0.0391	0.0571	0.0795	0.0963	0.1164
Std Err Coeff:	0.0346	0.0268	0.0398	0.0362	0.0262	0.0214	0.0246	0.0247	0.0242	0.0222	0.0322	0.0452	0.0547	0.0662

Note: Flows expressed in base-10 logarithmic scale

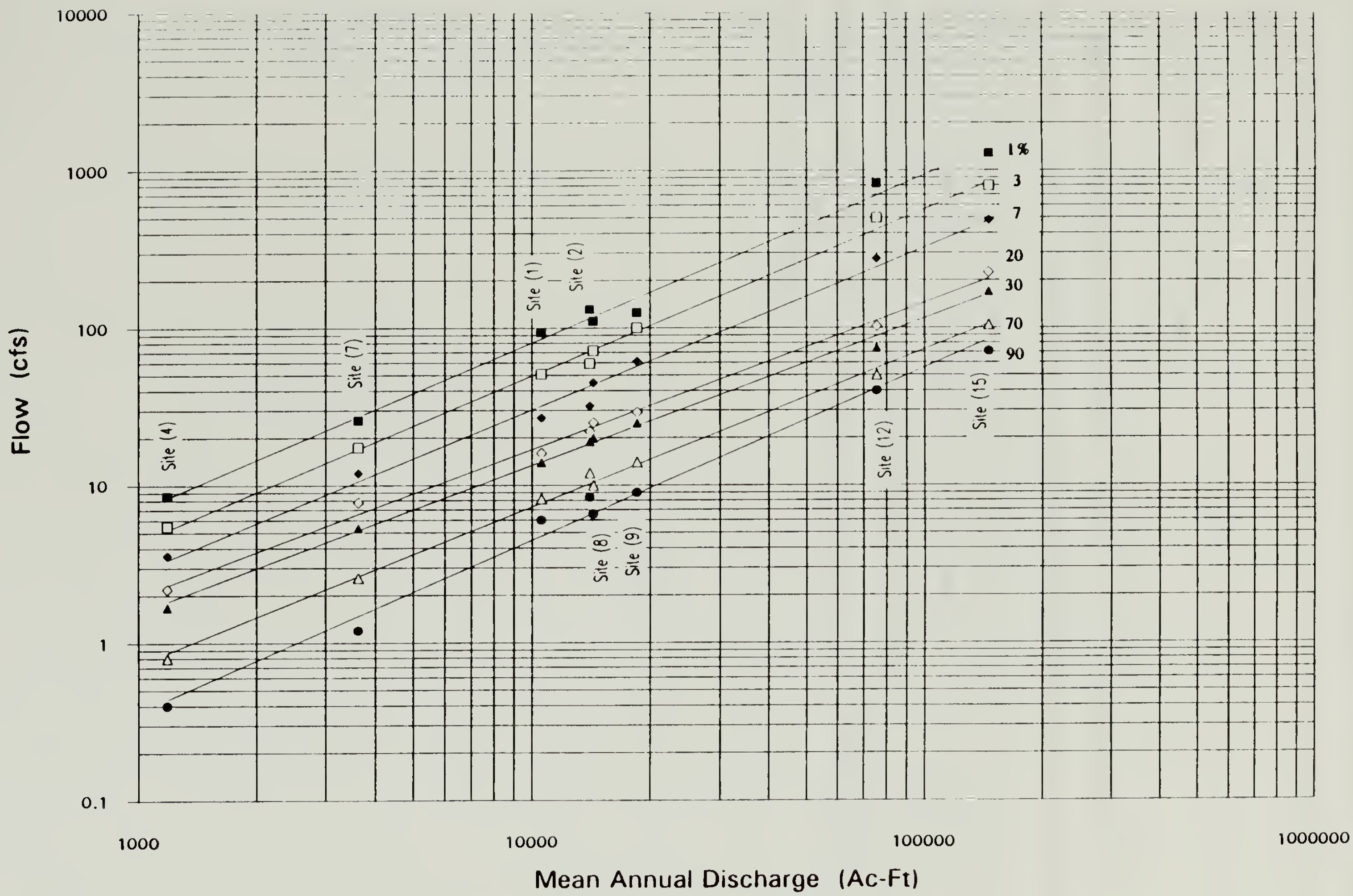

Fig.22 Parametric Flow Duration Analysis in the Zion N.P. Region

The parametric family of curves shown in Figure 22 is obtained by regressing flows at a specific probability of exceedance for all the selected stations (as the dependent variable) versus the corresponding mean annual flows (as the independent variable). Straight lines in the log-domain give the best regression relation of $q(\%)$ versus $\bar{Q}$ as defined by the expression

$$Log[q(\%)] = a + b * Log[\bar{Q}]$$

where parameters a and b are least-square estimates of the regression coefficients. The intercept a and slope b, the R-square and the standard errors obtained from the regression analysis, are shown at the bottom of Table 7. Given the set of curves in Figure 22, or better yet, the full set of regression equations, the flow duration curve at ungaged sites in the Zion region can be inferred, provided that an estimate of the mean annual flow at that particular location can be provided. The estimation of mean annual discharges at sites of interest will be the subject of a future report.

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Appendix I. Estimated Values of Statistics of Mean-Daily Flows of the NFVR at Springdale

Day	Mean	Standard Deviation	Skewness	Kurtosis	(-1) Serial Correlation	Coefficient Variation
1	59.000	63.759	6.563	49.0627	0.307	1.08
2	61.790	52.734	3.729	16.7528	0.747	0.85
3	55.806	33.346	3.928	20.1622	0.529	0.60
4	52.323	17.328	2.121	10.4912	0.497	0.33
5	53.726	22.733	2.431	10.0865	0.699	0.42
6	52.823	28.577	5.580	40.4921	0.785	0.54
7	50.371	14.045	1.107	4.3276	0.657	0.28
8	52.323	21.021	2.366	9.5524	0.761	0.40
9	49.806	13.263	0.936	3.7283	0.778	0.27
10	50.823	15.535	1.644	7.387	0.740	0.31
11	53.871	18.211	1.066	3.6713	0.624	0.34
12	81.726	158.058	6.147	42.9774	0.231	1.93
13	61.177	47.575	4.188	22.5956	0.745	0.78
14	55.161	38.077	6.507	49.7945	0.837	0.69
15	51.694	15.984	1.826	7.8236	0.649	0.31
16	53.871	18.038	1.551	5.696	0.664	0.33
17	52.065	13.600	1.073	5.078	0.802	0.26
18	54.839	23.370	3.486	18.7605	0.481	0.43
19	60.355	42.299	3.819	18.5457	0.392	0.70
20	56.694	27.355	3.535	18.7631	0.827	0.48
21	55.661	23.546	3.012	13.1867	0.831	0.42
22	54.048	16.145	1.611	6.016	0.825	0.30
23	53.839	17.701	2.970	16.5722	0.626	0.33
24	53.936	16.111	1.738	7.0728	0.768	0.30
25	53.823	16.218	1.769	7.2737	0.880	0.30
26	55.645	22.010	3.658	20.802	0.735	0.40
27	55.468	18.033	2.356	9.882	0.859	0.33
28	69.839	90.118	5.814	39.1141	0.344	1.29
29	77.742	119.719	5.286	31.0359	0.874	1.54
30	60.677	29.914	3.187	15.987	0.693	0.49
31	69.032	91.368	7.069	55.0335	0.427	1.32
32	56.161	17.913	3.304	19.1409	0.232	0.32
33	57.000	20.155	2.858	13.3626	0.787	0.35
34	59.919	41.038	5.184	31.485	0.874	0.68
35	53.855	13.537	1.620	6.4681	0.654	0.25
36	56.161	29.315	6.308	47.7123	0.741	0.52
37	59.452	37.099	4.727	26.628	0.757	0.62
38	57.742	24.672	3.715	19.9233	0.921	0.43
39	60.855	37.516	4.887	31.0094	0.288	0.62
40	56.081	20.071	3.131	16.7278	0.831	0.36
41	57.339	34.560	6.090	44.9372	0.302	0.60
42	54.500	18.962	4.436	29.5056	0.166	0.35
43	56.355	19.241	2.552	11.7019	0.659	0.34
44	55.565	19.678	4.258	27.4279	0.736	0.35

45	57.081	21.682	3.930	23.4509	0.521	0.38
46	54.871	11.749	1.241	6.1142	0.555	0.21
47	55.726	16.950	2.750	13.5051	0.569	0.30
48	58.290	30.959	5.838	42.2684	0.306	0.53
49	59.226	30.438	4.845	31.817	0.382	0.51
50	58.887	29.734	4.129	21.9047	0.752	0.50
51	54.968	13.283	1.139	5.7003	0.770	0.24
52	55.016	11.297	0.447	3.452	0.668	0.21
53	54.145	13.448	2.924	18.5565	0.758	0.25
54	64.436	70.035	5.972	39.9988	0.745	1.09
55	57.984	31.701	6.352	47.8214	0.651	0.55
56	60.726	40.395	6.347	47.609	0.277	0.67
57	56.839	26.043	5.505	38.720	0.349	0.46
58	52.855	9.960	0.342	3.5671	0.531	0.19
59	52.274	9.974	0.118	2.7789	0.833	0.19
60	56.210	28.267	6.051	45.4219	0.522	0.50
61	60.645	52.270	6.653	50.5959	0.366	0.86
62	54.177	14.896	1.433	6.2919	0.587	0.27
63	56.645	22.447	3.982	25.4525	0.561	0.40
64	57.065	21.326	2.430	9.9125	0.508	0.37
65	58.323	25.891	3.341	15.4916	0.616	0.44
66	69.984	128.390	7.762	62.9363	0.180	1.83
67	133.226	627.171	7.864	64.0178	0.981	4.71
68	67.710	121.110	7.723	62.5092	0.980	1.79
69	57.548	45.845	7.056	55.4497	0.970	0.80
70	53.806	18.879	2.560	10.8331	0.598	0.35
71	55.806	32.078	5.338	37.133	0.779	0.57
72	53.258	18.626	3.901	23.8989	0.941	0.35
73	55.548	34.338	6.380	48.1129	0.432	0.62
74	55.371	23.070	3.106	14.4405	0.270	0.42
75	53.177	24.133	5.499	39.8146	0.711	0.45
76	53.371	20.633	3.944	24.4138	0.904	0.39
77	54.710	27.409	5.860	43.2321	0.581	0.50
78	54.145	22.601	5.044	35.5566	0.951	0.42
79	54.758	16.214	2.932	15.952	0.491	0.30
80	52.484	10.703	0.797	3.5187	0.787	0.20
81	52.097	9.407	0.282	3.4424	0.853	0.18
82	52.984	10.237	0.676	4.4577	0.857	0.19
83	53.177	12.660	2.656	15.5653	0.690	0.24
84	56.774	35.163	6.133	45.1881	0.826	0.62
85	54.871	26.669	5.788	42.3799	0.348	0.49
86	67.968	113.211	7.488	59.8562	0.914	1.67
87	65.323	74.927	5.912	40.8136	0.918	1.15
88	64.806	65.594	4.330	21.2032	0.914	1.01
89	54.710	25.431	4.964	32.5257	0.863	0.46
90	53.823	24.497	5.260	35.9172	0.405	0.46
91	66.355	99.395	6.984	53.4599	0.858	1.50
92	52.210	13.481	2.062	10.4408	0.685	0.26
93	50.226	9.584	0.951	4.1062	0.704	0.19
94	49.339	9.178	0.925	4.4452	0.812	0.19
95	49.161	9.230	0.811	4.6321	0.844	0.19

96	49.194	9.605	1.214	6.1879	0.850	0.20
97	50.661	9.149	0.879	5.4415	0.888	0.18
98	53.629	14.410	3.431	20.1707	0.501	0.27
99	51.661	10.158	1.413	5.8226	0.494	0.20
100	52.097	10.575	1.133	5.0134	0.945	0.20
101	51.710	10.264	0.950	4.1804	0.863	0.20
102	53.952	21.062	5.851	43.5701	0.520	0.39
103	54.936	18.595	5.165	36.6591	0.963	0.34
104	58.081	39.276	6.990	54.4101	0.918	0.68
105	60.500	39.861	5.275	33.9628	0.873	0.66
106	68.242	108.583	7.613	61.2942	0.856	1.59
107	62.081	58.887	6.999	54.514	0.953	0.95
108	54.532	15.443	4.050	26.4296	0.873	0.28
109	54.226	12.105	1.220	5.4293	0.783	0.22
110	61.823	70.223	7.618	61.4108	0.580	1.14
111	56.403	21.171	5.350	37.932	0.909	0.38
112	59.048	38.095	7.018	54.9821	0.422	0.65
113	59.468	39.927	6.877	53.4761	0.966	0.67
114	56.161	20.400	5.216	37.2562	0.916	0.36
115	55.355	13.180	2.165	11.8215	0.888	0.24
116	55.742	12.067	1.389	5.9977	0.779	0.22
117	77.145	156.490	7.525	60.1326	0.293	2.03
118	66.097	61.172	6.015	41.5643	0.879	0.93
119	64.532	52.936	5.206	30.4977	0.952	0.82
120	57.403	16.092	2.361	10.8817	0.688	0.28
121	62.532	58.110	7.419	59.3038	0.448	0.93
122	64.952	76.750	7.614	61.3499	0.978	1.18
123	58.790	27.296	6.099	45.6989	0.940	0.46
124	59.016	22.282	4.769	31.1323	0.914	0.38
125	64.194	37.099	3.596	16.1443	0.566	0.58
126	59.355	21.295	3.681	18.706	0.760	0.36
127	61.194	28.003	4.726	29.7321	0.549	0.46
128	61.290	25.707	3.673	18.4252	0.945	0.42
129	61.226	18.101	2.305	9.6265	0.648	0.30
130	64.468	34.321	5.511	38.5472	0.480	0.53
131	67.500	36.442	4.293	23.5809	0.145	0.54
132	80.887	89.594	4.616	25.5171	0.795	1.11
133	71.613	64.606	5.739	39.1875	0.545	0.90
134	62.790	21.655	3.300	16.9823	0.640	0.34
135	72.097	68.640	6.482	48.1508	0.775	0.95
136	64.629	25.491	3.288	15.1393	0.564	0.39
137	115.210	373.726	7.789	63.1975	0.514	3.24
138	107.661	310.816	7.724	62.4798	0.980	2.89
139	79.516	92.692	5.604	37.2243	0.891	1.17
140	75.484	90.054	7.145	56.075	0.895	1.19
141	75.726	95.064	7.491	59.9864	0.973	1.26
142	75.403	93.545	6.618	48.8761	0.936	1.24
143	102.306	310.069	7.830	63.6498	0.931	3.03
144	71.129	59.135	6.530	49.3844	0.935	0.83
145	70.548	51.670	5.311	32.2992	0.702	0.73
146	79.500	62.992	3.957	20.1118	0.575	0.79

147	70.790	47.525	5.531	38.2807	0.655	0.67
148	74.419	63.193	5.431	35.6484	0.561	0.85
149	70.613	47.130	6.044	44.6975	0.241	0.67
150	66.806	24.705	2.362	10.2052	0.590	0.37
151	73.371	39.769	3.440	16.66	0.751	0.54
152	82.548	65.414	4.518	26.9126	0.437	0.79
153	93.081	95.621	4.109	20.3554	0.912	1.03
154	127.516	374.357	7.653	61.7111	0.630	2.94
155	91.516	108.073	4.668	26.3804	0.524	1.18
156	81.484	62.343	4.390	26.0725	0.732	0.77
157	76.323	37.404	2.424	9.2833	0.729	0.49
158	74.468	31.020	2.027	7.5806	0.856	0.42
159	74.887	28.783	2.187	9.7512	0.826	0.38
160	85.323	68.063	5.097	32.1771	0.658	0.80
161	80.436	40.421	3.281	16.1582	0.899	0.50
162	86.403	47.859	2.383	9.3864	0.657	0.55
163	90.129	59.677	2.636	11.0926	0.659	0.66
164	88.436	54.807	2.832	11.9499	0.808	0.62
165	91.065	71.874	5.508	39.2699	0.557	0.79
166	87.629	43.833	2.022	7.3665	0.733	0.50
167	87.210	49.204	3.180	14.854	0.520	0.56
168	85.419	40.806	3.405	18.5495	0.890	0.48
169	88.645	58.392	5.280	36.4557	0.886	0.66
170	86.452	40.945	3.330	18.0312	0.922	0.47
171	88.936	38.080	2.063	8.1612	0.725	0.43
172	85.323	34.370	2.012	8.1077	0.696	0.40
173	93.032	41.643	2.067	8.562	0.834	0.45
174	92.016	35.834	1.577	5.6625	0.755	0.39
175	92.387	34.853	1.334	4.6047	0.870	0.38
176	95.129	36.300	0.860	2.936	0.853	0.38
177	100.968	46.277	1.615	6.8036	0.863	0.46
178	114.774	74.167	2.411	10.5128	0.829	0.65
179	122.048	106.186	4.878	33.436	0.732	0.87
180	115.629	67.288	1.884	7.2389	0.837	0.58
181	118.500	69.626	1.651	5.3276	0.856	0.59
182	121.839	72.683	1.918	6.8792	0.928	0.60
183	128.936	87.156	1.985	6.8544	0.921	0.68
184	137.758	100.452	2.153	7.8285	0.909	0.73
185	138.323	88.363	1.790	6.719	0.902	0.64
186	145.161	89.804	1.453	4.8675	0.837	0.62
187	154.984	105.744	1.798	6.2192	0.932	0.68
188	165.710	131.465	2.351	8.7587	0.952	0.79
189	166.581	122.068	2.101	8.0715	0.920	0.73
190	178.919	163.719	3.074	15.0328	0.689	0.92
191	170.371	134.475	2.379	9.435	0.763	0.79
192	176.500	137.537	2.233	8.2613	0.943	0.78
193	189.645	140.061	1.887	6.6136	0.870	0.74
194	186.065	136.976	2.195	8.2942	0.898	0.74
195	197.661	146.126	1.920	7.1521	0.946	0.74
196	214.629	155.448	1.630	5.6529	0.957	0.72
197	235.065	185.463	1.794	6.7848	0.915	0.79

198	249.081	185.714	1.578	6.0983	0.962	0.75
199	263.323	196.334	1.334	4.8509	0.961	0.75
200	263.661	185.702	0.844	2.6275	0.902	0.70
201	269.000	196.812	0.890	2.7511	0.939	0.73
202	273.629	208.881	1.182	4.071	0.920	0.76
203	283.936	221.432	1.095	3.5784	0.934	0.78
204	298.355	240.336	1.323	4.4372	0.963	0.81
205	297.177	230.656	1.482	5.627	0.957	0.78
206	299.823	230.572	1.367	5.0374	0.953	0.77
207	303.000	231.538	1.168	4.0324	0.926	0.76
208	301.823	226.628	1.206	4.5414	0.935	0.75
209	311.581	263.131	2.136	9.617	0.942	0.84
210	314.565	242.572	1.444	5.5054	0.930	0.77
211	320.436	248.003	1.240	4.0215	0.950	0.77
212	322.581	244.720	1.133	3.8379	0.965	0.76
213	333.290	263.225	1.315	4.5009	0.958	0.79
214	338.210	272.918	1.497	5.5415	0.961	0.81
215	347.726	296.971	1.735	6.8833	0.965	0.85
216	354.161	297.830	1.731	6.8701	0.971	0.84
217	355.807	313.770	1.722	5.9678	0.958	0.88
218	362.129	342.614	1.848	6.0337	0.922	0.95
219	343.677	314.146	1.769	5.6417	0.954	0.91
220	340.258	310.678	1.633	4.9302	0.964	0.91
221	356.226	360.967	2.067	7.4432	0.938	1.01
222	367.065	374.866	2.178	8.544	0.972	1.02
223	347.936	323.104	1.595	4.8027	0.920	0.93
224	353.919	369.348	2.377	10.1128	0.891	1.04
225	352.290	358.142	1.995	7.4351	0.894	1.02
226	367.145	387.344	2.129	8.0488	0.932	1.06
227	357.903	359.524	1.880	6.8277	0.970	1.00
228	344.177	320.451	1.320	3.673	0.943	0.93
229	347.565	326.819	1.354	3.8848	0.967	0.94
230	335.339	323.863	1.363	3.8178	0.970	0.97
231	329.307	318.829	1.451	4.2873	0.962	0.97
232	331.274	325.503	1.385	3.8992	0.972	0.98
233	313.419	325.614	1.723	5.3136	0.949	1.04
234	301.516	318.177	1.938	6.7521	0.971	1.06
235	292.532	313.188	1.956	6.9803	0.976	1.07
236	281.823	309.500	2.110	7.9234	0.981	1.10
237	265.194	284.090	2.310	9.8229	0.963	1.07
238	258.903	282.812	2.466	10.8244	0.975	1.09
239	251.516	275.126	2.666	12.8873	0.973	1.09
240	236.871	270.899	3.090	16.0638	0.979	1.14
241	230.565	266.813	3.348	18.6449	0.981	1.16
242	227.984	261.976	3.203	17.5766	0.974	1.15
243	224.032	258.810	3.081	16.3719	0.956	1.16
244	203.016	235.845	3.585	20.8334	0.958	1.16
245	188.710	203.154	2.970	15.0864	0.975	1.08
246	181.597	189.282	2.664	12.2214	0.960	1.04
247	177.161	182.477	2.595	11.5469	0.963	1.03
248	166.403	174.622	2.939	14.3585	0.973	1.05

249	164.597	174.066	2.887	13.7907	0.967	1.06
250	161.016	168.281	2.774	12.5202	0.961	1.05
251	149.177	156.882	3.207	16.2621	0.971	1.05
252	138.387	137.872	3.351	18.0976	0.978	1.00
253	133.516	131.634	3.303	17.6822	0.954	0.99
254	125.194	122.274	3.727	21.6428	0.973	0.98
255	121.129	127.565	4.528	29.3528	0.976	1.05
256	113.758	106.875	3.936	23.8582	0.979	0.94
257	111.677	104.922	3.557	19.1333	0.954	0.94
258	106.919	93.881	3.872	23.4289	0.952	0.88
259	106.048	96.849	3.566	18.9772	0.925	0.91
260	101.306	84.995	3.552	20.2829	0.970	0.84
261	93.452	71.427	3.742	22.485	0.934	0.76
262	88.436	65.614	3.590	21.1196	0.977	0.74
263	84.871	60.094	3.506	20.5323	0.979	0.71
264	82.726	56.320	3.415	19.8357	0.977	0.68
265	84.436	62.303	3.198	15.3778	0.764	0.74
266	84.936	79.778	4.679	28.7489	0.927	0.94
267	79.597	52.465	2.921	13.9932	0.894	0.66
268	75.742	42.515	2.938	16.7984	0.907	0.56
269	74.048	40.423	2.772	15.0838	0.929	0.55
270	72.484	38.149	2.498	13.2997	0.959	0.53
271	69.403	36.086	2.720	15.184	0.961	0.52
272	69.694	37.053	2.227	10.0417	0.896	0.53
273	67.661	32.967	2.161	10.7741	0.936	0.49
274	65.968	32.554	2.040	9.0723	0.944	0.49
275	63.710	30.985	2.122	9.3735	0.973	0.49
276	62.274	26.737	1.697	8.0381	0.954	0.43
277	62.903	25.517	1.305	5.7558	0.883	0.41
278	60.968	22.565	1.153	5.2399	0.917	0.37
279	60.806	23.404	1.120	4.9909	0.955	0.38
280	62.097	28.247	1.628	6.1577	0.896	0.45
281	65.097	46.205	4.419	28.0314	0.857	0.71
282	65.355	41.673	3.706	21.7451	0.453	0.64
283	76.548	88.176	4.825	28.928	0.864	1.15
284	75.210	102.643	6.230	45.0225	0.533	1.36
285	64.871	42.349	2.913	12.9789	0.808	0.65
286	59.081	24.236	1.149	4.3801	0.785	0.41
287	57.597	22.444	0.878	3.4642	0.905	0.39
288	60.274	28.462	2.120	9.5436	0.718	0.47
289	57.403	18.739	0.451	2.7433	0.655	0.33
290	60.774	21.361	0.512	2.6254	0.817	0.35
291	59.419	19.817	0.533	3.0694	0.825	0.33
292	63.339	41.484	5.003	34.2766	0.637	0.65
293	71.565	92.532	6.733	51.561	0.295	1.29
294	63.016	31.433	2.431	10.8132	0.742	0.50
295	64.161	35.425	3.071	15.6589	0.489	0.55
296	62.774	36.545	4.501	30.3314	0.454	0.58
297	66.242	55.039	4.657	28.266	0.607	0.83
298	84.968	154.071	6.688	50.7771	0.821	1.81
299	64.565	46.236	3.724	18.9718	0.785	0.72

300	61.613	39.009	3.748	21.5548	0.854	0.63
301	65.403	44.556	3.179	14.69	0.659	0.68
302	78.097	110.929	6.551	49.688	0.260	1.42
303	63.758	37.925	2.533	10.2395	0.366	0.59
304	73.919	74.281	4.093	20.7214	0.428	1.00
305	70.145	74.286	6.247	46.2986	0.737	1.06
306	66.855	62.915	5.836	41.6687	0.915	0.94
307	74.452	71.930	4.416	24.9292	0.488	0.97
308	65.661	44.915	3.883	20.3933	0.662	0.68
309	76.952	78.875	3.806	18.1384	0.768	1.02
310	80.194	142.529	7.008	54.4891	0.670	1.78
311	62.048	40.422	3.528	18.705	0.097	0.65
312	60.242	50.899	5.572	38.715	0.914	0.84
313	65.323	53.205	3.758	18.6738	0.573	0.81
314	65.274	55.558	5.177	35.3623	0.440	0.85
315	68.790	56.078	4.051	23.1643	0.827	0.82
316	66.936	51.788	4.778	31.2637	0.430	0.77
317	61.339	27.355	1.722	6.4528	0.546	0.45
318	55.855	19.358	1.377	6.0912	0.758	0.35
319	58.226	25.521	2.177	9.7358	0.593	0.44
320	54.290	18.463	1.208	4.7941	0.787	0.34
321	61.323	40.694	4.072	24.1588	0.634	0.66
322	65.452	51.655	4.241	24.8834	0.869	0.79
323	62.726	46.798	4.033	20.7351	0.468	0.75
324	58.113	24.073	1.899	8.7367	0.779	0.41
325	60.258	30.967	3.110	17.1879	0.596	0.51
326	58.016	23.648	1.595	6.7489	0.792	0.41
327	56.790	21.309	1.444	5.0336	0.733	0.38
328	66.952	46.012	3.173	15.053	0.660	0.69
329	71.855	81.153	5.254	34.0858	0.561	1.13
330	57.484	23.775	1.581	6.261	0.622	0.41
331	78.371	184.502	7.744	62.7475	0.172	2.35
332	58.097	36.602	4.962	34.2189	0.884	0.63
333	58.290	45.640	6.654	51.5252	0.121	0.78
334	52.468	15.855	1.053	5.2857	0.716	0.30
335	54.758	26.481	4.425	29.9921	0.299	0.48
336	55.532	22.168	2.019	9.1491	0.321	0.40
337	58.161	39.228	4.800	31.2073	0.726	0.67
338	51.548	18.132	2.191	11.1793	0.301	0.35
339	51.645	25.195	5.067	35.7355	0.881	0.49
340	68.226	110.761	6.897	52.6826	0.085	1.62
341	69.629	92.802	4.986	28.0671	0.184	1.33
342	86.790	155.657	4.908	27.5786	0.671	1.79
343	68.306	69.336	4.068	19.8349	0.760	1.02
344	62.419	52.956	4.278	24.155	0.853	0.85
345	74.290	184.654	7.793	63.2626	0.783	2.49
346	56.177	32.406	4.288	26.6348	0.810	0.58
347	83.016	181.574	6.656	49.7134	0.461	2.19
348	55.306	30.963	2.829	11.3281	0.472	0.56
349	51.323	18.310	2.199	10.0851	0.851	0.36
350	50.048	15.491	1.408	6.5274	0.732	0.31

351	48.484	12.641	0.515	3.0194	0.787	0.26
352	78.371	178.526	6.136	41.6492	0.000	2.28
353	60.403	57.322	4.554	24.6078	0.625	0.95
354	65.194	88.146	5.571	34.902	0.072	1.35
355	57.532	59.788	6.900	53.4913	0.834	1.04
356	50.790	25.843	4.965	34.5632	0.935	0.51
357	50.936	21.626	3.034	14.9666	0.768	0.42
358	59.226	43.946	3.212	13.4758	0.668	0.74
359	63.613	91.768	7.054	55.1135	0.719	1.44
360	54.355	28.663	3.376	16.4508	0.715	0.53
361	54.274	31.643	4.517	27.929	0.404	0.58
362	57.887	63.015	7.130	56.1146	0.182	1.09
363	53.032	28.697	5.203	36.1003	0.311	0.54
364	51.371	19.361	3.015	16.7216	0.441	0.38
365	49.661	15.674	2.068	10.1909	0.574	0.32
Average --->	104.535	87.844	3.531	21.588	0.743	0.742
Maximum --->	367.145	627.171	7.864	64.018	0.981	4.708
Minimum --->	48.484	9.149	0.118	2.625	-0.000	0.181

Appendix II. Fourier-Fitted of Statistics of Mean-Daily Flows of the NFVR at Springdale

Day	Mean	Standard Deviation	Skewness	Kurtosis	(-1) Serial Correlation	Coefficient Variation
1	55.9814	40.527	3.9429	24.571	0.6002	0.72
2	55.8464	39.4925	3.9088	24.2198	0.6056	0.71
3	55.7325	38.5533	3.8726	23.8525	0.6111	0.69
4	55.6404	37.709	3.8346	23.4715	0.6167	0.68
5	55.5703	36.9576	3.7951	23.079	0.6222	0.67
6	55.5224	36.2956	3.7541	22.6778	0.6278	0.65
7	55.4965	35.7178	3.7121	22.2705	0.6333	0.64
8	55.4923	35.2182	3.6694	21.8601	0.6386	0.63
9	55.5091	34.7893	3.6261	21.4497	0.6438	0.63
10	55.5461	34.4231	3.5827	21.0424	0.6488	0.62
11	55.6023	34.1108	3.5396	20.6414	0.6536	0.61
12	55.6765	33.8434	3.497	20.2501	0.6581	0.61
13	55.7672	33.6116	3.4553	19.8717	0.6622	0.60
14	55.873	33.4064	3.4149	19.5095	0.666	0.60
15	55.992	33.2187	3.3761	19.1669	0.6694	0.59
16	56.1225	33.0403	3.3394	18.8469	0.6723	0.59
17	56.2626	32.8635	3.3051	18.5527	0.6748	0.58
18	56.4104	32.6816	3.2735	18.2872	0.6769	0.58
19	56.5639	32.4887	3.2449	18.0533	0.6784	0.57
20	56.721	32.2803	3.2197	17.8535	0.6795	0.57
21	56.8799	32.053	3.1982	17.6902	0.68	0.56
22	57.0386	31.8047	3.1806	17.5656	0.68	0.56
23	57.1954	31.535	3.1671	17.4817	0.6795	0.55
24	57.3485	31.2444	3.1581	17.4399	0.6784	0.54
25	57.4963	30.9351	3.1536	17.4416	0.6769	0.54
26	57.6374	30.6105	3.1538	17.4877	0.6748	0.53
27	57.7706	30.2753	3.1589	17.579	0.6723	0.52
28	57.8948	29.9353	3.1688	17.7156	0.6693	0.52
29	58.0091	29.5975	3.1836	17.8975	0.6659	0.51
30	58.113	29.2695	3.2033	18.1243	0.6621	0.50
31	58.2059	28.9598	3.2279	18.3952	0.658	0.50
32	58.2878	28.6775	3.2572	18.7089	0.6535	0.49
33	58.3585	28.4319	3.2911	19.0641	0.6487	0.49
34	58.4184	28.2326	3.3294	19.4588	0.6437	0.48
35	58.4678	28.0891	3.3719	19.8907	0.6385	0.48
36	58.5075	28.0106	3.4183	20.3575	0.6332	0.48
37	58.5382	28.0058	3.4684	20.8561	0.6278	0.48
38	58.5608	28.0829	3.5217	21.3836	0.6223	0.48
39	58.5766	28.2493	3.578	21.9365	0.6168	0.48
40	58.5867	28.5111	3.6368	22.5111	0.6114	0.49
41	58.5924	28.8737	3.6977	23.1037	0.6062	0.49
42	58.595	29.3407	3.7603	23.7103	0.6011	0.50
43	58.5961	29.9147	3.8241	24.3267	0.5962	0.51
44	58.5968	30.5966	3.8886	24.9486	0.5916	0.52

45	58.5985	31.3858	3.9533	25.5717	0.5873	0.54
46	58.6026	32.2802	4.0178	26.1917	0.5833	0.55
47	58.6102	33.2759	4.0814	26.8042	0.5798	0.57
48	58.6223	34.3675	4.1438	27.4048	0.5767	0.59
49	58.6399	35.5481	4.2044	27.9894	0.5741	0.61
50	58.6637	36.8093	4.2628	28.5538	0.572	0.63
51	58.6941	38.1412	4.3185	29.094	0.5704	0.65
52	58.7316	39.5328	4.371	29.6062	0.5694	0.67
53	58.7762	40.9717	4.4199	30.087	0.569	0.70
54	58.8279	42.4448	4.4648	30.5329	0.5692	0.72
55	58.8862	43.938	4.5055	30.9409	0.57	0.75
56	58.9506	45.4365	4.5414	31.3083	0.5714	0.77
57	59.0203	46.9252	4.5725	31.6328	0.5734	0.80
58	59.0941	48.3887	4.5983	31.9124	0.576	0.82
59	59.171	49.8114	4.6188	32.1453	0.5793	0.84
60	59.2493	51.1779	4.6338	32.3305	0.5831	0.86
61	59.3276	52.4734	4.6431	32.4669	0.5874	0.88
62	59.404	53.6833	4.6467	32.5543	0.5923	0.90
63	59.4768	54.7939	4.6447	32.5927	0.5978	0.92
64	59.544	55.7922	4.637	32.5825	0.6037	0.94
65	59.6035	56.6666	4.6237	32.5246	0.6101	0.95
66	59.6535	57.4065	4.6051	32.4202	0.6169	0.96
67	59.6918	58.0025	4.5813	32.271	0.624	0.97
68	59.7167	58.4469	4.5526	32.0792	0.6315	0.98
69	59.7262	58.7334	4.5192	31.8472	0.6393	0.98
70	59.7188	58.8573	4.4815	31.5778	0.6473	0.99
71	59.6929	58.8156	4.4399	31.2742	0.6556	0.99
72	59.6473	58.6071	4.3948	30.9399	0.6639	0.98
73	59.5807	58.2321	4.3467	30.5785	0.6724	0.98
74	59.4926	57.6926	4.2959	30.1941	0.6809	0.97
75	59.3823	56.9925	4.2431	29.7908	0.6894	0.96
76	59.2497	56.1371	4.1888	29.3731	0.6978	0.95
77	59.095	55.1332	4.1335	28.9454	0.7062	0.93
78	58.9185	53.9891	4.0778	28.5124	0.7144	0.92
79	58.7211	52.7148	4.0222	28.0787	0.7224	0.90
80	58.5039	51.3211	3.9674	27.6489	0.7302	0.88
81	58.2685	49.8202	3.9138	27.2278	0.7377	0.86
82	58.0167	48.2252	3.8621	26.8199	0.7448	0.83
83	57.7505	46.5503	3.8128	26.4297	0.7517	0.81
84	57.4725	44.8103	3.7665	26.0614	0.7581	0.78
85	57.1854	43.0206	3.7236	25.7194	0.7642	0.75
86	56.8921	41.1972	3.6847	25.4074	0.7698	0.72
87	56.5957	39.3564	3.6501	25.1292	0.775	0.70
88	56.2997	37.5147	3.6204	24.8881	0.7797	0.67
89	56.0075	35.6886	3.5959	24.6872	0.7839	0.64
90	55.7227	33.8948	3.5769	24.5292	0.7876	0.61
91	55.4489	32.1496	3.5638	24.4165	0.7909	0.58
92	55.1899	30.469	3.5567	24.3509	0.7936	0.55
93	54.9491	28.8688	3.5559	24.3341	0.7958	0.53
94	54.7303	27.3641	3.5615	24.3672	0.7976	0.50
95	54.5368	25.9695	3.5736	24.4509	0.7988	0.48

96	54.3719	24.6988	3.5923	24.5853	0.7996	0.45
97	54.2388	23.5651	3.6175	24.7705	0.7999	0.43
98	54.1403	22.5807	3.6491	25.0056	0.7998	0.42
99	54.0791	21.7568	3.6871	25.2896	0.7993	0.40
100	54.0576	21.1037	3.7312	25.6211	0.7983	0.39
101	54.0777	20.6306	3.7812	25.9981	0.797	0.38
102	54.1412	20.3457	3.8368	26.4184	0.7953	0.38
103	54.2495	20.2559	3.8977	26.8793	0.7933	0.37
104	54.4036	20.3669	3.9635	27.3776	0.791	0.37
105	54.6042	20.6833	4.0339	27.9101	0.7884	0.38
106	54.8515	21.2081	4.1083	28.4732	0.7856	0.39
107	55.1456	21.9433	4.1862	29.0627	0.7826	0.40
108	55.486	22.8893	4.2672	29.6747	0.7794	0.41
109	55.872	24.0453	4.3507	30.3046	0.7761	0.43
110	56.3027	25.409	4.4361	30.948	0.7726	0.45
111	56.7765	26.9766	4.5229	31.6001	0.769	0.48
112	57.2919	28.7431	4.6104	32.2562	0.7654	0.50
113	57.8469	30.7017	4.698	32.9115	0.7617	0.53
114	58.4396	32.8445	4.7852	33.5611	0.758	0.56
115	59.0674	35.162	4.8714	34.2003	0.7544	0.60
116	59.7279	37.6434	4.9558	34.8242	0.7507	0.63
117	60.4184	40.2763	5.0381	35.4282	0.7471	0.67
118	61.1361	43.0472	5.1175	36.0078	0.7436	0.70
119	61.8781	45.941	5.1936	36.5587	0.7402	0.74
120	62.6415	48.9418	5.2658	37.0768	0.7368	0.78
121	63.423	52.032	5.3337	37.558	0.7336	0.82
122	64.2198	55.1933	5.3967	37.9988	0.7305	0.86
123	65.0287	58.4064	5.4545	38.3959	0.7275	0.90
124	65.8467	61.6508	5.5067	38.7461	0.7246	0.94
125	66.6707	64.9056	5.5528	39.0469	0.7219	0.97
126	67.4977	68.149	5.5927	39.2957	0.7194	1.01
127	68.3247	71.3592	5.6261	39.4907	0.717	1.04
128	69.1489	74.5136	5.6527	39.6302	0.7147	1.08
129	69.9674	77.5898	5.6724	39.7129	0.7127	1.11
130	70.7774	80.5654	5.685	39.738	0.7107	1.14
131	71.5762	83.4183	5.6906	39.705	0.7089	1.17
132	72.3614	86.1268	5.689	39.6139	0.7073	1.19
133	73.1303	88.6701	5.6804	39.4648	0.7058	1.21
134	73.8805	91.0282	5.6646	39.2584	0.7045	1.23
135	74.6098	93.1821	5.642	38.9958	0.7032	1.25
136	75.3159	95.1144	5.6126	38.6783	0.7022	1.26
137	75.9968	96.8092	5.5766	38.3074	0.7013	1.27
138	76.6506	98.2521	5.5343	37.8852	0.7005	1.28
139	77.2754	99.431	5.4859	37.414	0.6998	1.29
140	77.8697	100.3357	5.4317	36.8961	0.6993	1.29
141	78.4321	100.9585	5.3721	36.3343	0.6989	1.29
142	78.9612	101.2939	5.3073	35.7315	0.6986	1.28
143	79.4563	101.3391	5.2377	35.0908	0.6985	1.28
144	79.9166	101.0941	5.1638	34.4154	0.6985	1.26
145	80.3417	100.5613	5.0859	33.7087	0.6986	1.25
146	80.7318	99.7462	5.0045	32.9741	0.6989	1.24

147	81.0871	98.657	4.9198	32.2151	0.6993	1.22
148	81.4086	97.3048	4.8325	31.4352	0.6999	1.20
149	81.6976	95.7032	4.7427	30.6378	0.7006	1.17
150	81.956	93.8688	4.6511	29.8265	0.7015	1.15
151	82.1864	91.8206	4.558	29.0046	0.7025	1.12
152	82.392	89.5802	4.4637	28.1755	0.7038	1.09
153	82.5765	87.1713	4.3686	27.3424	0.7052	1.06
154	82.7447	84.6199	4.2731	26.5084	0.7068	1.02
155	82.9019	81.9538	4.1776	25.6764	0.7087	0.99
156	83.0544	79.2024	4.0823	24.8492	0.7107	0.95
157	83.2093	76.3967	3.9876	24.0293	0.713	0.92
158	83.3745	73.5685	3.8937	23.2191	0.7155	0.88
159	83.559	70.7507	3.8008	22.4209	0.7182	0.85
160	83.7726	67.9766	3.7092	21.6365	0.7212	0.81
161	84.026	65.2797	3.6191	20.8678	0.7245	0.78
162	84.3306	62.6934	3.5307	20.1162	0.7279	0.74
163	84.6992	60.2507	3.444	19.3831	0.7317	0.71
164	85.1449	57.9838	3.3591	18.6694	0.7357	0.68
165	85.6817	55.924	3.2763	17.9761	0.74	0.65
166	86.3245	54.1012	3.1954	17.3038	0.7446	0.63
167	87.0884	52.5436	3.1167	16.653	0.7494	0.60
168	87.9895	51.2778	3.04	16.0238	0.7544	0.58
169	89.044	50.3281	2.9654	15.4163	0.7598	0.57
170	90.2683	49.7166	2.8928	14.8304	0.7653	0.55
171	91.6791	49.4629	2.8223	14.2659	0.7711	0.54
172	93.293	49.5842	2.7537	13.7224	0.7771	0.53
173	95.1264	50.0947	2.6871	13.1994	0.7833	0.53
174	97.1955	51.006	2.6222	12.6962	0.7897	0.52
175	99.5156	52.3267	2.5591	12.2121	0.7963	0.53
176	102.1014	54.0626	2.4977	11.7465	0.8031	0.53
177	104.9669	56.2166	2.4379	11.2984	0.8099	0.54
178	108.1246	58.7889	2.3795	10.8671	0.8169	0.54
179	111.5858	61.7768	2.3226	10.4517	0.8239	0.55
180	115.3603	65.175	2.267	10.0515	0.8311	0.56
181	119.4561	68.9758	2.2126	9.6655	0.8382	0.58
182	123.8793	73.1691	2.1595	9.2931	0.8453	0.59
183	128.6339	77.7425	2.1075	8.9336	0.8524	0.60
184	133.7218	82.6816	2.0567	8.5863	0.8595	0.62
185	139.142	87.9702	2.007	8.2507	0.8665	0.63
186	144.8916	93.5906	1.9583	7.9264	0.8733	0.65
187	150.9646	99.5236	1.9108	7.6129	0.88	0.66
188	157.3524	105.7488	1.8644	7.3101	0.8865	0.67
189	164.0435	112.2446	1.8192	7.0178	0.8929	0.68
190	171.0238	118.989	1.7751	6.736	0.899	0.70
191	178.2759	125.9592	1.7324	6.4647	0.9049	0.71
192	185.7799	133.1318	1.6911	6.2043	0.9105	0.72
193	193.5129	140.4834	1.6513	5.9549	0.9158	0.73
194	201.4492	147.9901	1.613	5.7171	0.9207	0.73
195	209.5607	155.6284	1.5765	5.4913	0.9254	0.74
196	217.8165	163.3748	1.5419	5.2781	0.9297	0.75
197	226.1833	171.2056	1.5093	5.0783	0.9337	0.76

198	234.626	179.0978	1.4789	4.8926	0.9373	0.76
199	243.107	187.0283	1.4508	4.7217	0.9405	0.77
200	251.5876	194.9745	1.4252	4.5667	0.9434	0.77
201	260.0268	202.914	1.4023	4.4283	0.9459	0.78
202	268.3834	210.8246	1.3823	4.3074	0.948	0.79
203	276.6143	218.6842	1.3652	4.2051	0.9498	0.79
204	284.6766	226.471	1.3514	4.122	0.9512	0.80
205	292.527	234.1635	1.3408	4.0592	0.9522	0.80
206	300.122	241.7395	1.3336	4.0174	0.953	0.81
207	307.4189	249.1776	1.33	3.9973	0.9534	0.81
208	314.3757	256.4557	1.3301	3.9997	0.9536	0.82
209	320.9514	263.5515	1.3339	4.0251	0.9535	0.82
210	327.1068	270.4427	1.3416	4.074	0.9531	0.83
211	332.8043	277.1066	1.3532	4.1468	0.9526	0.83
212	338.0086	283.52	1.3686	4.2436	0.9518	0.84
213	342.6868	289.6594	1.388	4.3646	0.951	0.85
214	346.8089	295.5009	1.4113	4.5098	0.9499	0.85
215	350.3477	301.0203	1.4384	4.6789	0.9488	0.86
216	353.2797	306.1931	1.4692	4.8716	0.9477	0.87
217	355.5844	310.9946	1.5038	5.0874	0.9465	0.87
218	357.2455	315.3997	1.5419	5.3256	0.9453	0.88
219	358.2502	319.3837	1.5834	5.5854	0.9441	0.89
220	358.5897	322.9218	1.6282	5.8659	0.943	0.90
221	358.2596	325.9898	1.6759	6.1659	0.942	0.91
222	357.2591	328.5639	1.7265	6.4841	0.9411	0.92
223	355.5921	330.6212	1.7796	6.8192	0.9403	0.93
224	353.2661	332.1397	1.8351	7.1696	0.9398	0.94
225	350.2929	333.0991	1.8925	7.5337	0.9394	0.95
226	346.6883	333.4804	1.9516	7.9097	0.9392	0.96
227	342.4718	333.2667	2.0122	8.2958	0.9392	0.97
228	337.6664	332.4434	2.0738	8.6901	0.9395	0.98
229	332.299	330.9985	2.1361	9.0905	0.94	1.00
230	326.3994	328.9224	2.1989	9.4952	0.9407	1.01
231	320.0002	326.2092	2.2617	9.9021	0.9417	1.02
232	313.1372	322.8562	2.3242	10.3092	0.943	1.03
233	305.8483	318.8641	2.3861	10.7144	0.9444	1.04
234	298.1732	314.2378	2.447	11.1157	0.9461	1.05
235	290.1539	308.9861	2.5067	11.5112	0.948	1.06
236	281.8333	303.122	2.5647	11.8991	0.9501	1.08
237	273.2558	296.6628	2.6209	12.2775	0.9524	1.09
238	264.466	289.6302	2.6748	12.6448	0.9548	1.10
239	255.5092	282.0502	2.7263	12.9993	0.9574	1.10
240	246.4303	273.9531	2.7751	13.3397	0.9601	1.11
241	237.2742	265.3736	2.821	13.6646	0.9628	1.12
242	228.0849	256.3504	2.8638	13.973	0.9655	1.12
243	218.9052	246.9257	2.9034	14.2637	0.9683	1.13
244	209.7768	237.1457	2.9395	14.5361	0.971	1.13
245	200.7396	227.06	2.9722	14.7894	0.9736	1.13
246	191.8316	216.7207	3.0013	15.0233	0.9761	1.13
247	183.0888	206.1827	3.0267	15.2374	0.9784	1.13
248	174.5446	195.503	3.0486	15.4318	0.9805	1.12

249	166.23	184.7399	3.0668	15.6065	0.9824	1.11
250	158.1731	173.9531	3.0815	15.7619	0.984	1.10
251	150.3996	163.2026	3.0927	15.8984	0.9852	1.09
252	142.9315	152.5479	3.1005	16.0167	0.9861	1.07
253	135.7883	142.0487	3.1052	16.1177	0.9866	1.05
254	128.9865	131.7628	3.1068	16.2022	0.9866	1.02
255	122.5391	121.7464	3.1056	16.2715	0.9862	0.99
256	116.4565	112.0533	3.1017	16.3268	0.9853	0.96
257	110.7458	102.7344	3.0955	16.3695	0.9839	0.93
258	105.4112	93.8369	3.0872	16.401	0.9819	0.89
259	100.4542	85.4043	3.077	16.423	0.9793	0.85
260	95.8735	77.4754	3.0653	16.437	0.9762	0.81
261	91.6653	70.0846	3.0523	16.4448	0.9725	0.76
262	87.8231	63.2604	3.0384	16.4481	0.9682	0.72
263	84.3385	57.0265	3.0238	16.4485	0.9633	0.68
264	81.201	51.4005	3.0089	16.4479	0.9578	0.63
265	78.3981	46.3946	2.994	16.4479	0.9518	0.59
266	75.9157	42.0145	2.9795	16.4502	0.9451	0.55
267	73.7386	38.2604	2.9655	16.4564	0.9379	0.52
268	71.8499	35.1263	2.9524	16.468	0.9302	0.49
269	70.232	32.6006	2.9405	16.4865	0.9219	0.46
270	68.8667	30.6663	2.93	16.5133	0.9132	0.45
271	67.7348	29.3005	2.9211	16.5494	0.904	0.43
272	66.8171	28.4758	2.9142	16.5962	0.8943	0.43
273	66.0941	28.1603	2.9094	16.6543	0.8843	0.43
274	65.5467	28.3177	2.9068	16.7248	0.874	0.43
275	65.1554	28.9084	2.9066	16.8082	0.8633	0.44
276	64.9017	29.8892	2.909	16.9051	0.8524	0.46
277	64.7673	31.2149	2.9141	17.0157	0.8413	0.48
278	64.7348	32.8381	2.9218	17.1402	0.8301	0.51
279	64.7873	34.7104	2.9324	17.2786	0.8187	0.54
280	64.909	36.7823	2.9456	17.4307	0.8073	0.57
281	65.0852	39.0046	2.9616	17.5963	0.7958	0.60
282	65.3021	41.3287	2.9804	17.7748	0.7844	0.63
283	65.547	43.707	3.0017	17.9657	0.7731	0.67
284	65.8086	46.0939	3.0256	18.1681	0.762	0.70
285	66.0764	48.446	3.0519	18.3812	0.751	0.73
286	66.3415	50.7227	3.0805	18.604	0.7403	0.76
287	66.5959	52.8868	3.1111	18.8353	0.7298	0.79
288	66.833	54.9048	3.1437	19.0741	0.7196	0.82
289	67.047	56.7472	3.1781	19.319	0.7098	0.85
290	67.2335	58.3887	3.2139	19.5689	0.7004	0.87
291	67.3891	59.8087	3.251	19.8222	0.6914	0.89
292	67.5112	60.9914	3.2892	20.0777	0.6828	0.90
293	67.5985	61.9254	3.3282	20.3339	0.6747	0.92
294	67.6501	62.6045	3.3677	20.5896	0.667	0.93
295	67.6661	63.0269	3.4075	20.8433	0.6599	0.93
296	67.6474	63.1954	3.4475	21.0939	0.6532	0.93
297	67.5952	63.1174	3.4872	21.34	0.6471	0.93
298	67.5114	62.8043	3.5266	21.5805	0.6414	0.93
299	67.3985	62.2712	3.5653	21.8144	0.6363	0.92

300	67.259	61.5368	3.6032	22.0407	0.6317	0.91
301	67.096	60.6227	3.64	22.2584	0.6275	0.90
302	66.9126	59.5533	3.6756	22.4669	0.6238	0.89
303	66.7121	58.3549	3.7098	22.6655	0.6206	0.87
304	66.4978	57.0555	3.7425	22.8538	0.6177	0.86
305	66.2732	55.6842	3.7735	23.0314	0.6153	0.84
306	66.0414	54.2708	3.8028	23.198	0.6133	0.82
307	65.8058	52.8449	3.8302	23.3537	0.6116	0.80
308	65.5692	51.436	3.8557	23.4984	0.6102	0.78
309	65.3345	50.0726	3.8792	23.6323	0.6091	0.77
310	65.1042	48.7814	3.9007	23.7558	0.6082	0.75
311	64.8807	47.588	3.9202	23.8694	0.6076	0.73
312	64.6658	46.5151	3.9379	23.9736	0.6071	0.72
313	64.4615	45.5835	3.9536	24.069	0.6068	0.71
314	64.269	44.8106	3.9674	24.1565	0.6065	0.70
315	64.0894	44.2109	3.9795	24.2369	0.6063	0.69
316	63.9235	43.7959	3.99	24.311	0.6062	0.69
317	63.7717	43.5732	3.9989	24.38	0.606	0.68
318	63.634	43.5473	4.0065	24.4447	0.6058	0.68
319	63.5105	43.7191	4.0127	24.5063	0.6056	0.69
320	63.4007	44.0858	4.0178	24.5657	0.6052	0.70
321	63.3036	44.6416	4.022	24.6241	0.6048	0.71
322	63.2187	45.3772	4.0254	24.6823	0.6042	0.72
323	63.1446	46.2806	4.0281	24.7414	0.6035	0.73
324	63.0801	47.3367	4.0303	24.8023	0.6026	0.75
325	63.0236	48.5284	4.0322	24.8658	0.6015	0.77
326	62.9736	49.8359	4.0339	24.9326	0.6002	0.79
327	62.9283	51.238	4.0356	25.0033	0.5988	0.81
328	62.886	52.7121	4.0374	25.0786	0.5972	0.84
329	62.8449	54.2344	4.0394	25.1587	0.5954	0.86
330	62.803	55.7806	4.0418	25.244	0.5934	0.89
331	62.7588	57.3262	4.0445	25.3345	0.5913	0.91
332	62.7103	58.847	4.0478	25.4302	0.5891	0.94
333	62.6558	60.3191	4.0516	25.531	0.5867	0.96
334	62.5939	61.7199	4.056	25.6364	0.5842	0.99
335	62.5229	63.0279	4.061	25.7461	0.5816	1.01
336	62.4416	64.2231	4.0666	25.8592	0.579	1.03
337	62.3487	65.2879	4.0729	25.975	0.5763	1.05
338	62.2433	66.2065	4.0796	26.0926	0.5737	1.06
339	62.1244	66.9653	4.0869	26.2108	0.5711	1.08
340	61.9915	67.5537	4.0945	26.3285	0.5685	1.09
341	61.8442	67.9636	4.1024	26.4443	0.566	1.10
342	61.6822	68.1893	4.1105	26.5568	0.5637	1.11
343	61.5055	68.2284	4.1187	26.6644	0.5615	1.11
344	61.3142	68.0807	4.1268	26.7656	0.5595	1.11
345	61.109	67.749	4.1346	26.8586	0.5578	1.11
346	60.8902	67.2386	4.1419	26.9419	0.5563	1.10
347	60.6589	66.557	4.1486	27.0138	0.5551	1.10
348	60.4161	65.7143	4.1546	27.0725	0.5542	1.09
349	60.163	64.7222	4.1595	27.1165	0.5536	1.08
350	59.9009	63.5944	4.1632	27.1441	0.5533	1.06

351	59.6315	62.346	4.1656	27.1538	0.5535	1.05
352	59.3563	60.9932	4.1664	27.1442	0.554	1.03
353	59.0772	59.5533	4.1655	27.114	0.5549	1.01
354	58.7961	58.0441	4.1626	27.062	0.5562	0.99
355	58.515	56.4834	4.1577	26.9871	0.5579	0.97
356	58.2358	54.8895	4.1506	26.8887	0.56	0.94
357	57.9607	53.28	4.1412	26.7659	0.5625	0.92
358	57.6915	51.6719	4.1293	26.6183	0.5654	0.90
359	57.4304	50.0815	4.1149	26.4458	0.5687	0.87
360	57.1795	48.5239	4.098	26.2483	0.5723	0.85
361	56.9403	47.0128	4.0785	26.0262	0.5763	0.83
362	56.7148	45.5605	4.0564	25.7798	0.5806	0.80
363	56.5048	44.1778	4.0317	25.5099	0.5851	0.78
364	56.3117	42.8734	4.0045	25.2176	0.59	0.76
365	56.1367	41.6544	3.9749	24.904	0.595	0.74
Average --->	104.535	87.844	3.531	21.588	0.743	0.794
Maximum --->	358.590	333.480	5.691	39.738	0.987	1.289
Minimum --->	54.058	20.256	1.330	3.997	0.553	0.373